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USER'S GUIDE FOR THE SAS (STAND-OFF ATTACK SIMULATION) COMPUTER MODEL

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This guide describes the use and application of the SAS (Stand-Off Attack Simulation) computer model. SAS is an effective survivability and security system design tool which allows an analyst to compare the relative effectiveness of selected survivability and/or security system upgrades to a threat involving the use of stand-off direct or indirect weapon fire. The program evaluates damage to both personnel and material targets. Scenarios which require either fixed (static) or mobile (dynamic) situations, or both may be modeled.

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INTRODUCTION

The SAS computer model was developed by JAYCOR to assist in the evaluation of survivability and security of weapon movement within the TNF (Theater Nuclear Forces). In performing this work, it was quickly discovered that many scenarios involved both security and survivability considerations. The interplay between security and survivability was often so tightly knit that analysis of the two factors independently would not provide a realistic solution. For example, consider the case of a ground movement scenario which involves the attack on a ground convoy by a land based special operations team (SOT). The objective of the SOT is to destroy or inflict sufficient damage to the weapons being transferred as to render them inoperative.

Survivability models have been developed which will evaluate the damage delivered to these weapons from sustained direct or indirect fire. Likewise, security models will enable the analyst to evaluate the number of defense and attack personnel incapacitated during engagement. Unfortunately, in our investigation of available computer models used to solve problems of this nature, we were unable to locate a model which would adequately combine the aspects of security and survivability in a realistic manner.

In general, security models simulated force-on-force engagement encounters, concentrating on attack force personnel firing at defense personnel and vice versa. We were unable to find a security model which could evaluate personnel firing at a combination of "material" type targets and "personnel" type targets.

Survivability models which were investigated permitted analysis of both material and personnel type targets; however, they did not allow for modification in defense force or attack force strategy. Realizing these deficiencies, an attempt was made to develop a methodology which would integrate necessary components of survivability and security, providing damage analysis for both material and personnel targets, as well as allowing the analyst to modify defense and attack force strategy. The methodology to combine both key survivability and security concerns has been developed and implemented into a computer model called SAS (Stand-Off Attack Simulation).

The objective of this report is to familiarize the reader with the methodology, use, and potential application of the SAS computer model. SAS analysis methodology is described in Section 1. This section also includes a description of specific areas of model application, a discussion of the advantages and disadvantages of the modeling technique used, and a list of possible improvements to the model which would simplify data input, increase simulation detail, and expand the areas of possible model application.

A summary of input required to execute the SAS model is presented in Section 2.

Section 3 describes an example scenario in detail. This scenario will be used to illustrate a possible application of the SAS model and step the user through an example execution. All input data is described in the text and examples of simulation output is included. The usefulness of SAS output data is best illustrated through an example such as that provided in Section 3. For this reason, this section also contains a description of the type of output data generated.

Section 4 contains a terminal session description for the example scenario outlined in Section 3. This section steps the user through the SAS execution of the example scenario, illustrating the interactive questions used to obtain input data and the format used to enter input data in response to each question type.

Appendix A contains sample standardized input data forms which are used to describe the details unique to a particular analysis. Following the blank data forms are completed forms showing all data required to perform execution of the example scenario described in Section 3.

Appendix B provides a description of the SAS model flow structure. Also included are descriptions of the expected storage requirements, operating system, source language used, and description of the computer system on which the code is currently installed.

Appendix C contains a fully documented code listing of the SAS model, including all subroutines used (excluding system furnished routines) and the INCLUDE file. The INCLUDE file contains parameter values which define the size of arrays and constants used within the SAS model.

Appendix D contains additional mathematical detail not provided in Section 1.

SECTION 1

ANALYSIS METHODOLOGY

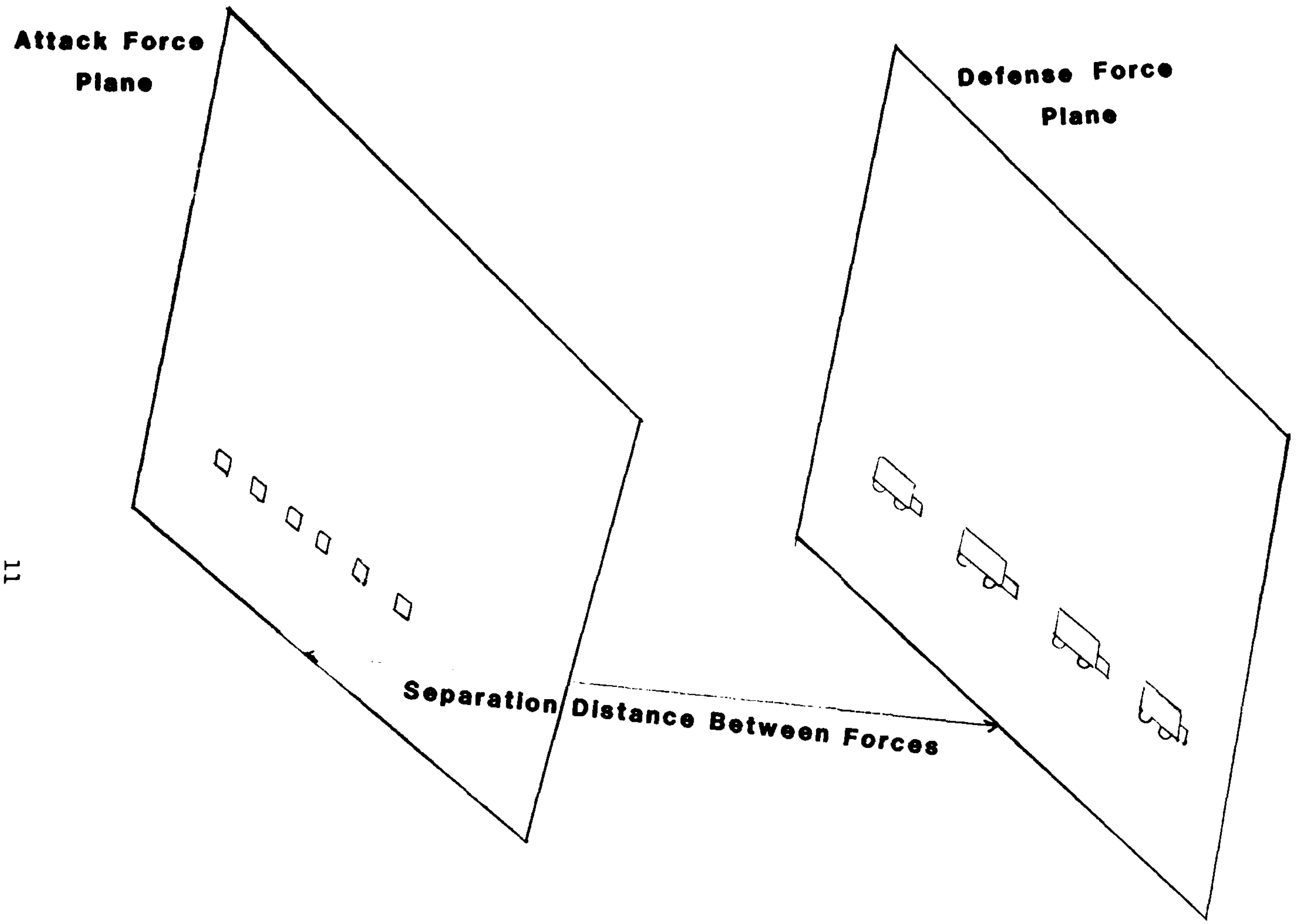
1.1 BACKGROUND

SAS is a two-dimensional simulation engagement model. Engagements involve the analysis of opposing force personnel and may include damage to selected material targets if desired. Attack force personnel and material targets are assumed to lie in a geometric plane parallel to the plane containing defense personnel and material targets (Figure 1.1). Movement of personnel and material targets is permitted during the simulation provided all movement is in either a horizontal or vertical direction within the respective attack and defense force plane. The sizes of personnel and material targets are governed by the vulnerable cross-sectional area of the target as viewed from the opposing plane. Targets, either of personnel or material type, are described in terms of rectangular shapes. Target position is specified relative to a fixed origin by x and y coordinate values corresponding to the lower left-hand corner of the rectangular target.

Attack or defense force fire is directed toward aim points located in the opposing force reference plane. Aim points are generally located in the center of an opposing target; however, they need not be directly related to any target nor appear within any opposing target area. This flexibility permits SAS to simulate "scattered" weapon fire from either attack or defense force personnel.

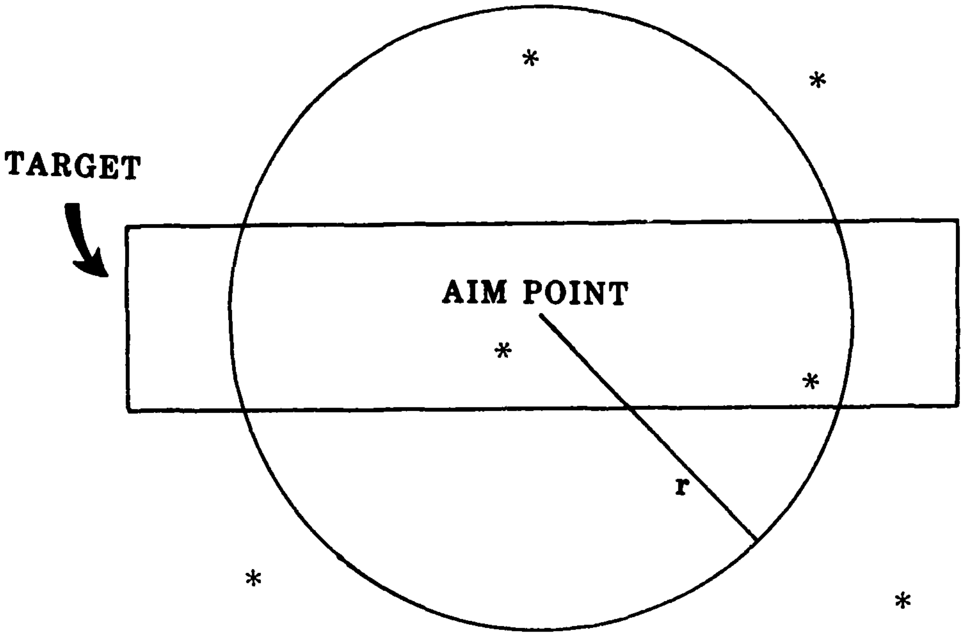
1.2 MODELING TECHNIQUE

The model uses Monte Carlo sampling techniques to determine the probability a given target is hit by opposing weapons fire. To obtain the probability that a player, firing at a particular aim point, may hit a particular target, a given number of shots are fired by the player at the aim point. The number of times the target is hit is divided by the total number of shots fired (refer to Figure 1.2). Once probabilities of target hit have



Personnel and Material Target Size is Represented as the Cross-sectional Area Which is Vulnerable to Opposing Weapon fire.

Figure 1.1 Parallel Plane Concept Used to Describe Size and Position of Opposing Force Personnel and Material Targets.



$$P(\text{Target is hit}) = \frac{\sum(\text{Number of shots hitting target})}{\text{Total number of shots fired}}$$

$$= \frac{2}{6} = .33, \text{ for this example.}$$

where,

r - Defines the radius of a circle around the aim point within which one-half of all shots fired are expected to land .

* - Denotes a sample hit point selected at random.

Figure 1.2 Monte-Carlo Techniques Used to Evaluate Probability of Hit

been determined for all possible players, aim points, and targets, these hit probabilities are used to modify the probability that a particular target will still exist with time. An event scheduling array is maintained which allows SAS to identify the next event to occur. An "event" can be any one of the following:

- a player may be selected to fire;
- a player may select a new weapon to fire, or the firing rate of the player's weapon may be modified;
- an aiming delay may be specified before a particular player may fire his next round;
- a player or target may stop or start moving in a different direction;
- the strategy of a particular player may change (i.e., a modified set of aim points may be selected for a particular player);
- the cover provided a target may change.

Strategy for attackers or defenders is defined by assigning a set of aim points, which are ordered by priority for each attacker or defender involved in the simulation. The probability that an attacker will continue to fire at a specific aim point is proportional to the probability that the primary target associated with that aim point is not destroyed.

SAS begins by computing probabilities of target hit by use of Monte Carlo techniques for each possible combination of firer, aim point, and target. These probabilities are stored in a three-dimensional array, denoted by $P_{NF,NAM,NT}$, where NF is the maximum number of firers, NAM is the number of possible aim points, and NT is the number of possible targets. $P_{i,j,k}$ contains the probability firer i fires at aim point j and hits target k.

In order to compute each $P_{i,j,k}$, a specified number of shots are fired at aim point j. Each shot fired is assumed to follow a Rayleigh distribution with an aiming error defining the firer's accuracy. The Rayleigh distribution function is given by:

$$P_I = \int_0^{\infty} \frac{r}{\sigma^2} e^{(-r^2/2\sigma^2)} dr$$

where r is the distance from the aim point and P_I is the probability that the shot fired lands within a circle of radius r centered around the aim point.

For purposes of the SAS model, aiming error is defined as the radius of a circle in which one half of the shots fired are expected to land. The "hit point" of each shot within the opposing force reference plane is expressed by x and y coordinates relative to the reference plane origin. To generate x and y coordinates from the Raleigh distribution, uniform random variables are generated. These uniform random variables are then transformed to normal random variables having mean $\mu=0$ and variance $\sigma=.8493r$. The variance σ, expressed as a function of r, is used to insure that the expected probability of a shot landing within r distance of the aim point is 0.5. Refer to Appendix D for the detailed description of how random variables are generated from the Raleigh distribution.

Factors which effect aiming error are divided into four categories: mechanical, environmental, human, and "other". Mechanical factors would include the weapon bench CEP, amount of weapon recoil, anomalies in the symmetrical weight of the round fired and the trueness of the bore of the weapon barrel, for example. Wind (which could effect projectile flight), the degree of darkness (i.e., daylight, dusk, twilight, etc.), fog, terrain, or smoke (which could reduce the probability that the firer selects the proper aim point at which to fire) would be considered as environmental factors. Human factors would include the amount of training the firer has had, the recency of training, and the effects of stress on the individual.

Other factors which affect aiming error include:

- the amount of time available to the firer to aim between rounds fired,

- the degree of which either the firer or the target is moving,
- possible target camouflage,
- distance between firer and target,
- firer's weapon type,
- maximum effective range of weapon.

SAS uses deterministic techniques to combine the target hit probabilities generated by Monte Carlo methods into the probability a certain target exists after N seconds have elapsed from the start of the simulation. The probability that a given set of targets exists with time can be combined to yield the expected number of targets destroyed with time.

SAS maintains a one-dimensional array which contains the probability that each target involved in the simulation exists with time. The probability of existence for a given target is modified whenever a member of the opposing force is selected to fire and may either hit the target directly or inflict damage to the target collaterally. If a firer is selected to fire and may hit the target directly or indirectly, the probability that the target exists after the firer fires his first shot is modified by the probability that the target is not destroyed by the firing event. Let P_{TE}^{t} = P(the target exists before firing event occurs). For the direct hit situation, P_{TE}^{t+1} is computed to reflect the probability that the target still exists after the firing event occurs as follows:

$$P_{TE}^{t+1} = P_{TE}^{t}(1.-P_{AS}P_{FE}P_{TH})$$

where:

P_{TE}^{t+1} = Probability target exists after shot is fired.

P_{TE}^{t} = Probability target exists before shot is fired.

P_{AS} = Probability that this particular aim point is selected.

P_{FE} = Probability that the firer still exists to fire (i.e., the probability that this firer has not been destroyed previously).

P_{TH} = Probability that the target is hit given the firer fires at the particular aim point.

Recall that the probability a given target (i) is hit, assuming a particular firer (j) fires at a particular aim point (k), has been computed previously and is stored in $P_{i,j,k}$. P_{TH} may be replaced by $P_{i,j,k}$ when refering to a specific target, firer, and aim point.

The variables enclosed in parentheses, $1.-P_{AS}P_{FE}P_{TH}$, represent the probability that the target is not destroyed by this shot. Thus, the probability the target exists after the shot is fired is equal to the probability it exists before the shot is fired multiplied by the probability that the target is not destroyed by this shot.

Whenever a firer is selected to fire, he may have more than one aim point at which to fire. Assume that N contains the number of aim points that the firer may select. Then the probability that target i exists after firer k fires his shot is expressed by:

$$P_i^{t+1} = P_i^t \sum_{k=1}^{N} (1. - P_k P_j P_m)$$

where:

P_i^{t+1} = P(target i exists after firer j fires the shot)

P_i^t = P(target i exists before firer j fires the shot)

P_k = P(firer j selects aim point k to fire at)

P_j = P(firer j exists to fire)

P_m = P(target i is hit if firer j fires at aim point k)

This expression can be further reduced to:

$$P_i^{t+1} = NP_i^t - P_i^t P_j \sum_{k=1}^{N} P_k P_m$$

To analyze the effect of indirect target damage, the probability that the target exists may be expressed as:

$$P_i^{t+1} = \sum_{n=1}^{M} P_n^t (1. - P_j \sum_{k=1}^{N} P_k P_m)$$

where:

P_i^{t+1}, P_j, P_m, P_k, and N have been described previously,

M = Number of targets which if hit would result in collateral damage to target i,

P_n^t = P(that target n exists before firer j fires next shot), where target n is a target which if hit causes collateral damage to target i,

P_m = P(that firer j fires at aim point k and hits target n), and

N = Number of aim points that firer j may fire at and hit target n.

Probabilities of target existence are mcdified as the simulation progresses by both the direct hit and indirect hit expressions. After the simulation time reaches the maximum time desired by the analyst, the simulation model stops and lists the probability of target existence for each target involved in the simulation. The analyst may also list the probability of target existence at intermediate times during the simulation.

After probabilities of target existence have been developed, targets possessing similar characteristics (such as defense or attack force personnel) can be grouped together and the expected number of targets destroyed or damaged can be calculated over time. This allows the analyst to estimate the expected size of the remaining defense force or attack force at preselected points in time. Any targets, such as number of vehicles destroyed, number of (nuclear) weapons damaged, etc., may be grouped in this manner with their expected number remaining with time calculated.

Standard conditional probability techniques are used to determine the expected number of grouped targets that are destroyed at a particular point since the beginning of the simulation. Assume that the array P_i for $i = 1,N$ contains the probability that attack force personnel 1 through N exist after 10 seconds have elapsed in the simulation. From this data, it is possible to obtain the expected number of attack force personnel which have been killed. First, the probability that exactly r attack force personnel remain after 10 seconds is computed. For this example, r would range from $r = 0$ (no attack personnel remain) to $r = N$ (all personnel remain). Let P_r = P(exactly r attack personnel remain). $P_{r=0} = \prod_{i=1}^{N} (1 - P_i)$, which is the probability that attacker 1 has been killed x probability that attacker 2 has been killed x ...probability that attacker N has been killed. The computer can rapidly evaluate all combinations required to generate P_r for each possible value of r.

After all P_r values have been obtained, the expected number of attack force personnel killed (denoted by E_k) is evaluated via the expression:

$$E_k = \sum_{i=1}^{N} iP_r$$

by definition of expected value.

For a more complete description of the methodology used by the SAS computer model, the user is requested to read the documentation provided within the computer code listing, Appendix C.

1.3 SPECIFIC AREAS OF APPLICATION

The SAS code is a generalized survivability model applicable to a wide variety of situations in which adversaries fire weapons at guards and at critical system components from prescribed distances. This includes scenarios involving ambush of a ground or air convoy, mortar or RPG attacks on a fixed site during outloading or maintenance, missile or bombing attacks on a secured fixed site, and attacks by any kind of stand-off weapon on unhardened field sites or dispersal locations. The model is specifically not applicable to attacks involving theft or sabotage of a covert nature. The computer model PANL (Path ANaLysis, Reference 3) should be used for covert or stealth type attacks.

Specific applicability of the model to a large number of situations with currently deployed or under-development weapon systems is foreseen. These potential applications are discussed in a general way in the following paragraphs. Included in the discussion are Pershing, Lance, and the Ground Launched Cruise Missile (GLCM).

Pershing, because of the requirement for quick reaction capability, is vulnerable at QRA (Quick Reaction Alert) sites to conventional bombing or to attack by terrorists or special operations teams (SOT) using a variety of weapons. Mortars, rocket propelled grenades, missiles, automatic and semi-automatic weapons and small arms are a few of the weapons which terrorists or SOTs might use in attacking QRA sites from a standoff position. Trucks, tanks, helicopters or fixed-wing aircraft might be used in the attack.

SAS is applicable to the analysis of Pershing QRA sites when various types of survivability or security enhancements are being considered. Berms, revetments, and various types of soft and semi-soft shelters may be analyzed. Armored blankets and personnel shelters or armored fighting positions may be included in the analysis as well.

The attack modes described above may be mounted against other systems during uploading for dispersal or for non-emergency relocation. GLCM and LANCE must be mobilized and formed into convoys for dispersal, and smaller weapons, whether or not they are protected by armored storage containers, undergo a period of high vulnerability when they are removed from igloos and loaded onto trucks, helicopters, or aircraft. A well-planned standoff attack, timed to coincide with a dispersal or relocation operation, could constitute a significant threat during the period when efficient mobilization for war is imperative. Analysis of scenarios involving this kind of attack, with variation on mobilization and dispersal procedures and equipment, could provide significant improvement.

The standoff mode of attack is the one most likely to be used against Pershing, Lance, or GLCM while in convoy to deployed positions or while hiding in the woods. Such an attack requires less detailed planning by an agressor than does a penetration attack, and there is less risk to him. He will maintain his position at a distance from the target, and thus will be able to escape more easily. This is true whether the attacking weapons are bombs, missiles, or long-range rifles, and whether the adversary mobility is by aircraft, trucks, or on foot.

It seems apparent that SAS could and should be used to analyze the vulnerability of real systems to a number of real threats. Improvement options now under development could be analyzed to determine whether they provide increased survivability under attack situations which are highly credible. We believe that SAS can provide a useful methodology in a realm which bridges the area between the security threat and considerations which have totally to do with survivability.

1.4 ADVANTAGES OF THE SAS MODEL

The SAS computer model offers the analyst complete control over all parameters which significantly effect the outcome of a small scale engagement situation. The SAS model accomplishes this goal while enabling the analyst to complete an analysis in a relatively short time-frame. By use of standardized data input forms, the completeness and correctness of all input data can be assured before executing the model. After the model is executed, data is entered from the input forms directly in a specified order, thus minimizing data entry time. SAS execution time is minimized by limiting the amount of Monte Carlo analysis to determining only probabilities of hit. All other calculations are analytical in nature, involving the use of conditional probability and expected value techniques, which are more efficiently handled by the computer. SAS evaluates the probability that personnel and material targets remain undestroyed with time. Thus definition of engagement termination criteria, such as the attack force refusing to continue after 25 percent of their total force has been killed, is left entirely for the analyst to define.

1.5 DISADVANTAGES OF THE SAS MODEL

Some simulation models are entirely Monte Carlo in nature, allowing the model to determine at any point in time whether a particular player is still alive or has been killed previously. This feature is useful if the analyst requires a deep level of detail. Using a model of this type, the analyst could develop a type of "script language" which could specify the actions of the various players based on other player's situations. For example, the analyst could model a scenario in which player 1 would move to a new location based on whether player 2 is still alive or has been killed. With SAS, the analyst has the capability to move a particular player to a new location by specifying the time relative to the beginning of the simulation when the movement of the player is to occur. Because SAS considers only the probability that a particular player has been killed, decisions cannot be made based on the "condition" of individual players. If this amount of detail is required, a code which employs Monte Carlo techniques throughout is suggested.

1.6 UNIQUE FEATURES OF THE SAS MODEL

Several unique features were built into the SAS model which were not generally available in other security models surveyed. These features have been found to be extremely useful in evaluating security/survivability concerns. (Reference 4)

- Specified groups of targets may be selected for further analysis to determine the expected number of targets remaining with time. In addition to the typical engagement outcome results describing damage to the defending and attacking forces, the user is able to obtain engagement damage to any set of targets. The type of targets which may be analyzed include vehicles, both ground based and air-borne, and any vital cargo being transported. Thus, in addition to providing security/survivability outcome, the output from SAS may be useful in logistics analysis where the expected number of vehicles destroyed, for example, would be important.

- Some targets may contain other targets; for example, a truck may contain a weapon container assembly which may contain a warhead, a fuzing mechanism, and an arming mechanism. This permits detailed analysis of each vulnerable component involved in the security system analysis.

- The model is also capable of evaluating the probability of target destruction in which the exact position of the target is not known, for example, the unknown target position of a weapon container in the bed of a canvas-covered truck, or personnel hidden by thick foliage in which their exact location cannot be determined.

- The degree of obscurity that a particular target or set of targets may possess can change during the simulation, for example, smoke canisters may be released during an engagement which could decrease the ability of firers to determine the exact location of enemy targets.

- Automatic weapon fire covering a random area may be modeled with SAS, as well as weapons which provide blast kill capability such as grenade launchers or rocket batteries, for example.

- SAS also has the capability of analyzing collateral target damage. Certain targets, if hit, may destroy or inflict damage on other targets. For example, vehicle fuel tanks, when hit with incendiary fire, could ignite, inflicting damage on personnel and material targets within the vehicle.

1.7 AREAS FOR FUTURE DEVELOPMENT

Possible improvements to the SAS model are discussed in this section. Each improvement or refinement will be described and the reason the improvement would be useful and the additional capability it will provide is discussed. Improvements to be discussed fall primarily within the following major areas:

- Simplification of Input Data Entry

  Those improvements which increase the ability of an analyst to generate and enter the data necessary to perform a simulation. These improvements would also reduce the time required to modify original data in order to analyze additional improvement options.

- Provide Additional Simulation Detail

  Improvements which increase the detail of the simulation or provide a more "real world" analysis capability.

1.7.1 Target Movement

Presently, the SAS user must model target movement by analyzing the target in a series of fixed positions along the movement route. This technique may be used to analyze target movement by means of situation "snap shots" which freeze the target's position for a finite number of steps along the movement path. An improvement would permit the analyst to specify a beginning and ending position for a particular target along with its' movement rate. The computer would calculate the target's position at a particular instant in time. This capability would reduce the amount of input data required to describe target movement and would eliminate discontinuities in output which often appear when the movement route is broken into a series of fixed positions.

1.7.2 Graphics Tablet for Data Entry

Interactive data entry using a digitizing graphics tablet would greatly reduce the amount of time required to specify terrain, cover, and target shape. Since input time would be reduced, more targets could be modeled in more detail.

1.7.3 Graphics Package for Verification of Input Data

Graphics software would display target shapes viewed at various perspective angles verifying the correctness of input data prior to simulation execution. This would permit an analyst to identify the vulnerable cross-sectional area of the target as viewed from a particular opposing force member's point of reference. The analyst could then use this information, or a subroutine could be developed, to evaluate the probability that the opposing force member could hit the target using the proper target orientation.

1.7.4 Data Base Development

A generalized data base would be constructed containing the sizes and physical characteristics of various targets and weapon types. The SAS user could then refer to this data base to acquire the data required for his particular simulation. This data base could either be computerized, allowing the analyst to select and incorporate the data automatically, or the data could be contained in document form in a manner compatible with the data entry format used by SAS.

1.7.5 Confidence Interval Estimation

The simulation model could be expanded to include confidence interval estimation. Generation of confidence intervals helps the analyst interpret the accuracy of the simulation results.

1.7.6 Relaxation of the Parallel Plane Restriction

Currently, opposing force personnel and material must reside in either the attack or defense force planes. Movement of personnel or equipment out of these planes is presently not permitted. This improvement would permit the analyst to specify all target positions in terms of x, y, and z coordinates. The coordinates specified would be relative to a single, fixed point origin in space, thereby allowing the analyst to place attack and defense force targets at any position desired.

1.7.7 Three-Dimensional Targets

Targets may be represented as three-dimensional volumes. Targets would be constructed of adjoining quadrilateral plates. The targets would be rotated to the "line of fire" from opposing force personnel and then the vulnerable cross-sectional area of the target would be computed for the firer's weapon type before the probability of hit is calculated.

1.7.8 Target Protection

Targets which cannot be destroyed or damaged by one round of opposing fire are not presently considered. For example, a payload well protected with armored blankets could not be damaged by an attack force using small caliber weapons assuming a single round direct hit, because the round would not penetrate target protection. It is understood, however, that subsequent rounds fired on or near the impact point of the first round could weaken the target protection sufficiently to result in payload damage or destruction.

The "multiple hit" possibility for those targets which require more than one direct hit to penetrate target protection should be incorporated into the SAS model. This improvement will permit the SAS model to analyze more complex survivability-oriented scenarios.

SECTION 2

INPUT DATA DESCRIPTION

Input data required for a typical SAS execution is divided into five major categories:

- Target Data

Target data is used to describe the size and shape of all personnel and material targets the user wishes to consider in the simulation.

- Firer Data

Data which describes a potential firer's characteristics, such as weapon type and response time, are included within this section.

- Aim Point Data

The aim point data section describes locations of aim points which may be fired at by opposing force personnel during the simulation.

- Target Status Change Description

Data describing a particular target's movement, size or shape change, or selection of new weapon type during the simulation would be included in this section.

- Other Input Data

This section contains all other input data not included within the first four categories. Names used for output files created during the simulation execution would be one example of the type of data required for this category.

The data required for each category is discussed in more detail in the text which follows.

2.1 TARGET DATA DESCRIPTION

For purposes of the SAS model, targets are objects whose destruction or damage benefits the opposing force in the engagement. If we assume a ground movement scenario in which a ground convoy is ambushed by a ground based attack force, possible targets of interest for the attack force would be defense personnel, the vehicles used to transport defense personnel and payload, and the payload itself. Attack personnel would be considered as possible targets for defense personnel. Targets are modeled by SAS as two-dimensional rectangular areas.

To allow for situations in which the exact position of the target is not revealed to the attacker, it is possible to specify an area in which the target may be placed. To clarify this feature of the SAS model, assume that the payload, which the attacking force is attempting to destroy, is located somewhere on the bed of a large truck in which the rear section of the truck is covered with canvas, preventing the attack force from directly determining the exact payload location. Further, assume that the size of the payload is small relative to the size of the canvas-covered truck bed. A target of this type can be modeled using SAS by defining the size of the target (the payload in this example) and specifying a random area in which the target may be located (the rear of the canvas-covered truck).

In some situations, certain targets, if hit, may inflict damage to other targets near by. For example, suppose the fuel tank of a vehicle was modeled as a target. The tank, when hit with incendiary attacker fire, could igniite and inflict damage to other targets such as defense personnel or vital payload. Lacking a better term, we will call this type of indirect target damage "collateral" damage. For each target identified and defined as input to the model, a list of targets which would be collaterally damaged by hitting this target must be specified. Before executing the SAS model, all targets must be identified and their size and position defined.

Due to aiming error, a firer may attempt to hit one target and actually hit another. For this reason, a list of targets which could be hit by firing at a specific aim point is required.

A standardized target data collection form used to obtain all required target information is presented in Appendix A. This data form also specifies data required to describe firer characteristics for personnel targets capable of firing at opposing forces.

There are several data items required to define each target to the SAS model. The format and use of each data item will be discussed separately as they appear on the data form, Appendix A, Figure A.1b.

2.1.1 Target Number

First, the user must select a target number. The target number selected for each target must be unique. Normally, targets are assigned numbers in sequence (1,2,...); however, the user may choose to assign target numbers in any order.

2.1.2 Target Description

Following the target number is the target description. Target description consists of at most 10 characters which are used to uniquely identify targets to the user. Any printable character may be included in the target description.

2.1.3 Target Height, Width

The height and width of the rectangular target area is measured in meters.

2.1.4 Random or Fixed

The user must now decide whether the target is random (lies within a random area, exact location is unknown to the opposing force) or fixed (the opposing force can recognize exact target location). An 'R' is entered indicating the target is found within a random area or an 'F' is entered indicating the target is in a fixed location. The user must specify either an 'R' or an 'F' for each target listed.

2.1.5 Lower Left Coordinate

For fixed targets, the user enters the x and y coordinates specifying the position of the lower left corner of the rectangular target areas. The coordinate values are relative to the origin in target's reference plane. The x coordinate is the distance in meters from the origin in the horizontal direction. The y coordinate is the distance from the origin to the lower left corner in the vertical direction.

For random targets, the user enters the x and y coordinates specifying the lower left corner of a random target area within which the target is located. The x and y coordinate values are expressed in meters defining the horizontal and vertical distance for the geometric plane origin.

2.1.6 Random Area Height, Width

For random targets, these parameters specify the height and width of the random target area in meters. Random area height and width are left blank if a fixed target is specified.

2.1.7 Can Target Fire?

If the target is a personnel target capable of firing at the opposing force, the user enters a 'Y' indicating the target can fire; otherwise, an 'N' is entered. Either a 'Y' or 'N' must be specified for each target involved in the simulation.

2.1.8 Weapon Type

The user identifies the type of weapon used by entering a one or two digit number. The weapons currently defined for use within the SAS model are listed below with their associated weapon-type number.

Weapon Type	Weapon Description
1	M16
2	AK47
3	M60
4	50 Caliber
5	M79
6	RPG
7	M19

The weapon type is left blank if the target cannot fire.

2.1.9 Number of Rounds

The user enters the number of rounds of ammunition available. This parameter is left blank if the target cannot fire.

2.1.10 Response Time

Response time specifies the time at which the firer begins firing at opposing forces relative to the beginning of the simulation (time = 0) measured in seconds. The parameter is left blank if the target cannot fire.

2.1.11 Aim Points, Ordered by Priority

Aim point numbers of those aim points which the firer may fire at during the simulation are ordered on their importance to the firer. When fire is first initiated, the firer will attempt to hit the first aim point listed. As the simulation progresses, the probability that the firer continues to fire at the first aim point decreases proportionally to the probability the primary target associated with the aim point has been previously destroyed. Aim point numbers are left blank if this target cannot fire.

2.1.12 Collaterally Damaged Targets

A list of those targets which will be destroyed if this t-rget is hit by the opposing force is the last data item required for target description. The order of the target numbers specified is not important. If fewer targets are specified than spaces on the data sheet, leave the rest of the spaces blank.

2.2 FIRER DESCRIPTION

Each attack and defense force member firing at the opposing force must be described. The description includes specification of a weapon type, response time (time when firer begins shooting), amount of ammunication available, and strategy. A summary of the input parameters describing a firer's characteristics (can target fire, weapon type, number of rounds, response time, and aim points ordered by priority) appearing on the target data form have been discussed in the previous section.

2.3 AIM POINT DATA DESCRIPTION

A firer's strategy is defined by providing a set of aim points which are ordered in terms of priority. Each aim point is associated with a primary target. Normally, the aim point is defined in the center of the particular situation modeled. In addition to the primary target, a list of other targets in close proximity to the primary target which may be hit by firing at this aim point must be provided. In some cases, it is more desirable to define a region for an attacker or defender to fire into than a specific point at which to aim. This is especially true if the exact position of the intended target cannot be determined. SAS allows spray of fire into an area by defining a rectangular shaped area in place of a fixed aim point. Shots are fired randomly into the rectangular area assuming each section of the area is equally likely to be fired into.

An sample form used to gather required aim point data is presented in Appendix A, Figure A.1c. The data items required for aim point description are in this section.

2.3.1 Aim Point Number

The aim point number is a unique number which the user assigns to each aim point considered in the simulation. Aim point numbers are usually defined in sequence (1,2,...); however, they may be assigned in any order which may be more convenient to the user.

2.3.2 Aim Point Description

The user must specify a unique aim point description which consists of at most 10 characters for each aim point desired. Any printable character is permissible within the aim point description. Normally, the aim point description references the primary target associated with the aim point.

2.3.3 Random or Fixed

If the user wants to define the aim point as fixed, an 'F' is entered; otherwise, a 'R' is used. Fixed aim points specify fixed points located in the plane containing the opposing force personnel and equipment to be fired at. Fixed aim points are specified whenever the opposing force can obtain an exact location of the opposing target area center.

Random aim areas, indicated by a 'R' entry, are used whenever the exact location of an opposing target area is unknown or the strategy is to spray automatic weapon fire evenly throughout an area without aimming specifically at any target.

The user must define each aim point considered as either random or fixed.

2.3.4 X Coordinate, Y Coordinate

If the aim point is fixed, the x and y coordinate values specify the location of the aim point in the opposing force reference plane. The x and y coordinate values measure, in meters, the horizontal and vertical distance from the origin to the aim point. Normally, for fixed aim points, the aim point is placed in the center of the primary target associated with the aim point.

If the aim point is random, the x and y coordinates specify the location of the lower left corner of a random aim area measured in meters from the opposing plane origin.

2.3.5 Height, Width

Height and width are only specified when a random aim point is desired. The height and width, expressed in meters, indicates the size of the random aim area. These data fields are left blank if a fixed aim point is used.

2.3.6 Targets Which May be Hit by Firing at This Aim Point

The last data entered on the aim point data form involves a list of possible targets which may be hit when this aim point is fired at. The first target number entered is considered the primary target associated with the aim point. Order of subsequent target numbers is not important. Should the user specify fewer target numbers than spaces on the data form, the remaining spaces should remain blank. The target which is closest to the aim point or most likely to be hit by firing at the aim point should be listed as the primary target.

2.4 TARGET STATUS CHANGE DATA

A target status change is specified by entering four parameters: the old target number, the new target number, the time the status change occurs, and the delay time for the new target to commence firing after the status change occurs. The data form used to obtain target status change information appears in Appendix A, Figure A.1d. The target status change parameters are now discussed in more detail.

2.4.1 Old Target Number

The old target number is the number of the original target assigned at the beginning of the simulation. This number identifies the target whose status will be modified.

2.4.2 New Target Number

The new target number points to a new set of target information which will replace the target information previously obtained when referencing the old target number. Information pertaining to the new target is transferred to the old target, destroying previous information used to define the old target characteristics.

2.4.3 Status Change Time

Status change time specifies the time in seconds from the start of the simulation when the target status change is to occur.

2.4.4 Delay Time

The user may choose to specify a delay time before the new target commences firing after the status change is complete. The delay time parameter can be used to specify a player's reload time, aim time, or time required to acquire a new weapon .

2.5 OTHER INPUT DATA

Other data required to perform a SAS simulation primarily concerns the specification of input and output files, names, starting and ending time for simulation results, and manner in which results are stored when the simulation is complete. Due to the self-explanatory nature of these parameters, they are not described within this section. Refer to Appendix A, Figure A.la and Figure A.le, for questions asked to obtain additional input parameters required to perform a SAS simulation.

SECTION 3

EXAMPLE APPLICATION

The application of the SAS model to evaluate the outcome of an ambush attack on a nuclear convoy will be presented. The objective of the attack is to destroy or render the weapons being transported by the convoy inoperative. The scenario details and modeling assumptions required to evaluate the engagement outcome are presented in two sections: scenario overview and scenario details. The scenario overview describes the scenario in a general sense and is used to acquaint the reader with the situation just prior to ambush. The second section, scenario details, provides more detailed assumptions concerning movement rates, weapon characteristics, number and location of defense and attack force personnel, vehicle type and size, and both attack/defense personnel cover and protection.

3.1 SCENARIO OVERVIEW

A nuclear convoy is transporting weapons to a fixed storage site. The convoy is enroute on a public highway when the attack occurs. The convoy consists of nine vehicles which carry defense personnel, nuclear weapons and required communication equipment. The attack on the convoy occurs without forewarning; hence, the defense force is taken totally by surprise. The attack is initiated by detonation of pre-placed mines under the roadway used by the convoy. Detonation of these mines is timed to effectively destroy the lead weapon-carrying vehicle and prevent further progression of remaining weapon-carrying vehicles beyond the mine detonation point. The mine detonation also isolates vehicles and personnel which have proceeded beyond the mine detonation point from involvement in the ensuing engagement between defense and attack forces concerned with protection and destruction of weapons in remaining weapon-carrying vehicles. Figure 3.1 shows a "bird's eye" view of the scenario situation just prior to mine detonation.

The attack force consists of 11 men who have pre-positioned themselves in well-hidden, protective foxholes or behind large trees to minimize the amount

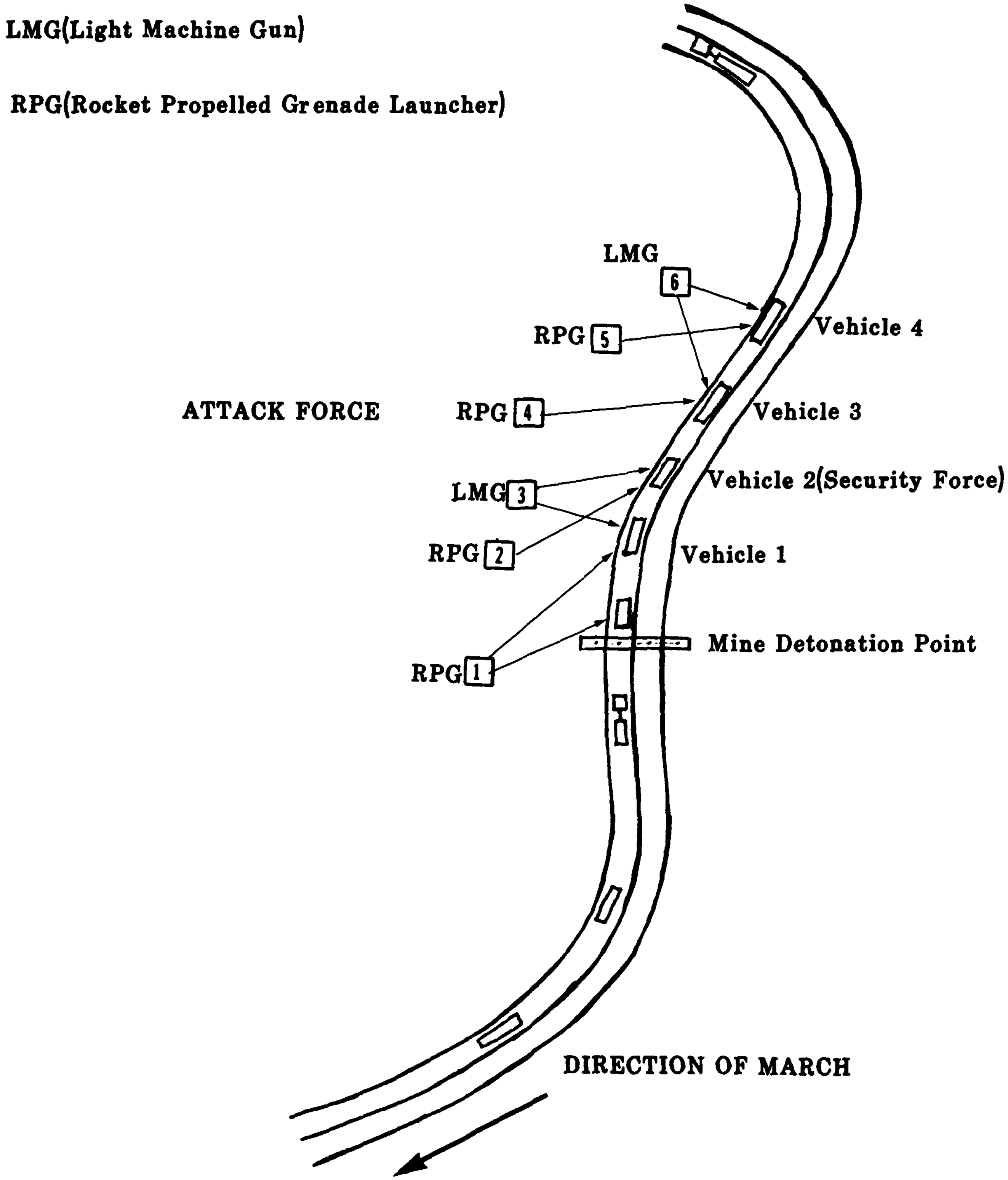


Figure 3.1 "Bird's Eye" View of Ambush Scenario Just Prior to Mine Detonation

of body area exposed to defense force weapon fire. Each attack force member has well-defined objectives and strategy when the engagement starts. A portion of the attack force is used to tie down the three lead vehicles and the one trailing vehicle, preventing personnel on these vehicles from directly assisting personnel located on weapon carrying vehicles throughout the engagement. It will be assumed that the attack force personnel used to pin down defense personnel in the lead and trailing vehicles will not enter into the engagement between defense personnel on remaining weapon carrying vehicles. Thus, the encounter situation which will be modeled by SAS involves the remaining six attackers (numbered 1-6 in Figure 3.1) and the defense personnel on trucks (numbered 1-4).

Since the attack occurs without forewarning, defense personnel do not respond with return fire immediately. In all cases, the first person responding from each vehicle is the assistant driver. After the vehicles have stopped, defense personnel located in the rear section of each vehicle, along with the vehicle driver, will respond. The vehicles will attempt to proceed through the ambush area, if possible. Although the defense vehicles have limited off-road capability, the attack force has carefully chosen its ambush site to prevent vehicles from continuing beyond the mine detonation point. The vehicles are assumed to stop on the roadway grouped fairly closely together, with the lead vehicle approximately five meters from the mine detonation point.

The convoy is in continuous communication with an additional back-up response force. Once the attack has been determined, the back-up response force is notified via personnel in the command-control and communications vehicle. The time required for the back-up force to respond to the ambush attack is five minutes. Due to the expected short duration of the engagement, additional support provided to the defense personnel on Trucks 1-4 by the back-up response force will not be considered.

3.2 SCENARIO DETAILS

All necessary assumptions required to perform the simulation, with the exception of specific individual player strategy and collateral target damage assumptions, are described in this section. The purpose of this section is to:

- describe assumptions used in this particular example, and
- familiarize the reader with the parameters which must be identified and defined prior to performing any simulation involving the use of the SAS computer model.

3.2.1 Convoy Composition

The nuclear convoy, shown in Figure 3.1, is composed of four load-carrying vehicles, one security personnel vehicle and the lead and trailing escort vehicles. Each load-carrying vehicle contains three nuclear projectiles within a standard container. The security vehicle contains six security personnel and equipment. The vehicles composing the convoy are ordered as follows:

- Route recon vehicle
- Command-control and communications vehicle
- Security-lead vehicle (M115)
- Two load-carrying vehicles
- Security force vehicle
- Two load-carrying vehicles
- Trailing security vehicle

3.2.2 Security Force Distribution

All vehicles contain a driver and assistant driver, both trained and equipped with issue M16 rifles. All load-carrying vehicles are equipped with an M60 as well as the M16 rifles. The ambush procedure of mine detonation under the first load-carrying vehicle isolates the three leading vehicles from the main body, while the trailing security vehicle is also diverted by direct fire. These security elements are, therefore, unable to directly assist the main body. The force-on-force encounter then involves principally security force personnel (drivers and guards) of load-carrying mission vehicles and the security guard vehicle personnel, excluding the defense personnel on the lead load-carrying vehicle which was destroyed by the mine detonation.

3.2.3 Personnel Assumptions

Defense personnel are assumed to remain completely exposed to fire. Since time involved in the stand-off attack phase of the SOT assault is only 20 seconds, it is assumed that if a defender sustains a hit, he will be considered ineffective in providing retaliatory fire. For this reason, defenders, while in moving vehicles, are assumed to have 0.9 square meters of cross sectional area exposed to fire. Defenders in moving vehicles are modeled as rectangles with height of 1.2 meter, width of0.75 meters. Figures 3.2 through 3.13 show the size and position of defense personnel within their respective vehicles.

Notice that in each of the figures there is a number associated with each vehicle and each defender within a particular vehicle. These numbers will be used to uniquely identify each defender involved in the simulation. For example, D1T1 denotes Defender 1, Truck 1. Similar numbers are used to uniquely identify weapons, weapon containers, defense force vehicle engine areas and members of the attacking force. W1T1, K1T1, and ET1, for example, will be used to denote Weapon 1, Truck 1, container for Weapon 1, Truck 1, and Truck 1 engine area, respectively. A1 is used to uniquely identify attack force member 1.

After vehicles stop, defense personnel are assumed to be limited in their selection of possible defense positions. By scenario definition, the convoy is being attacked from the right. On the left side is a steep drop which cannot be used effectively for defensive positions and precludes vehicle maneuvering. Thus security personnel are forced to take defensive positions behind their respective vehicles. Security personnel remain in prone positions exposing approximately0.04 square meters of their body to fire, modeled as a rectangular target 0.15 meters high, 0.25 meters wide. Figures 3.10-3.13 show the position of defense personnel after vehicles have stopped, while Figures 3.6-3.9 are the intermediate positions.

Attack personnel are in defensive positions exposing only their heads to

Truck 1
Just Prior to Mine Detonation

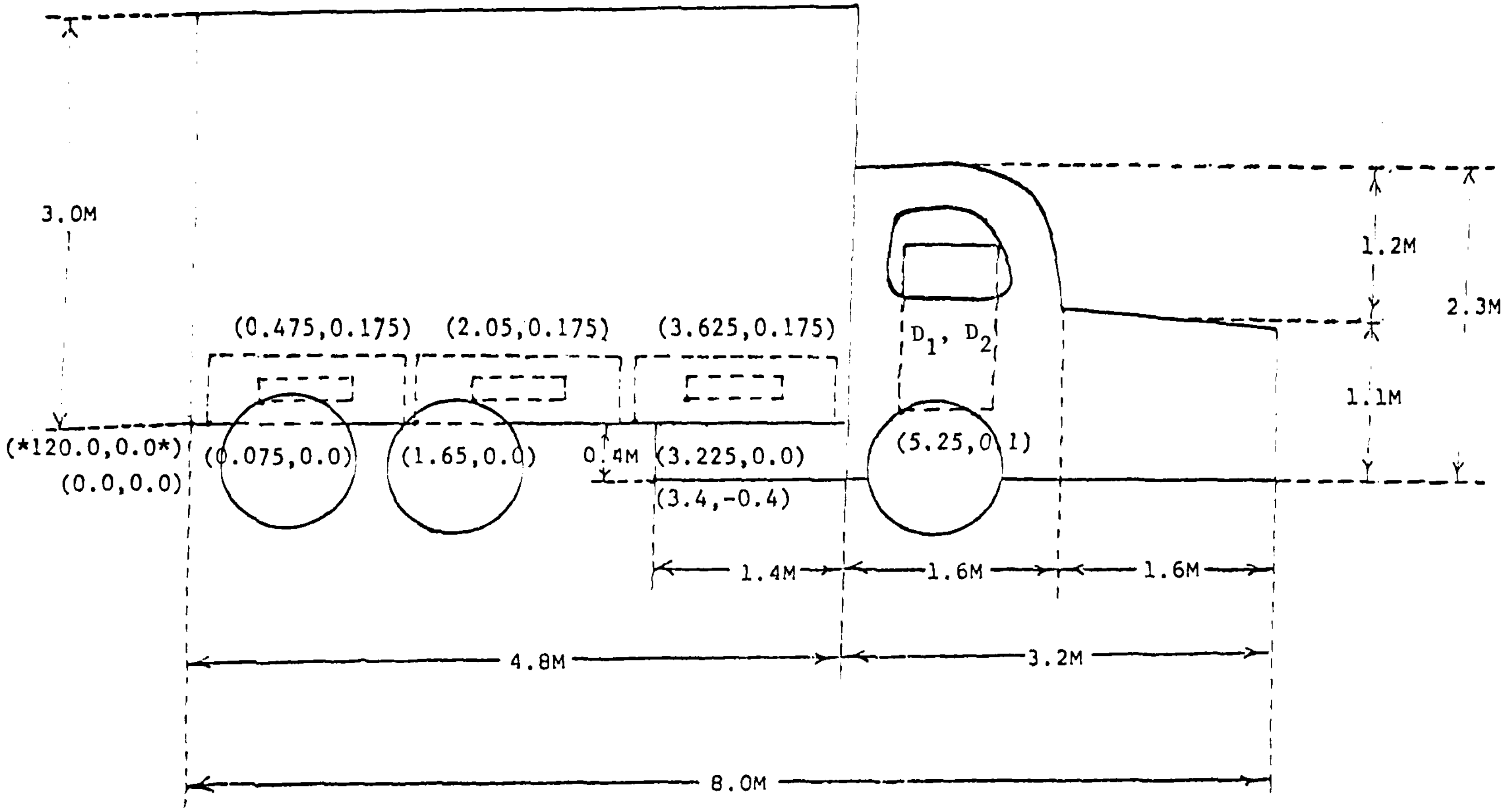


Figure 3.2 Defender Target Locations, Truck 1, Position 0

Truck 2
Just Prior to Mine Detonation

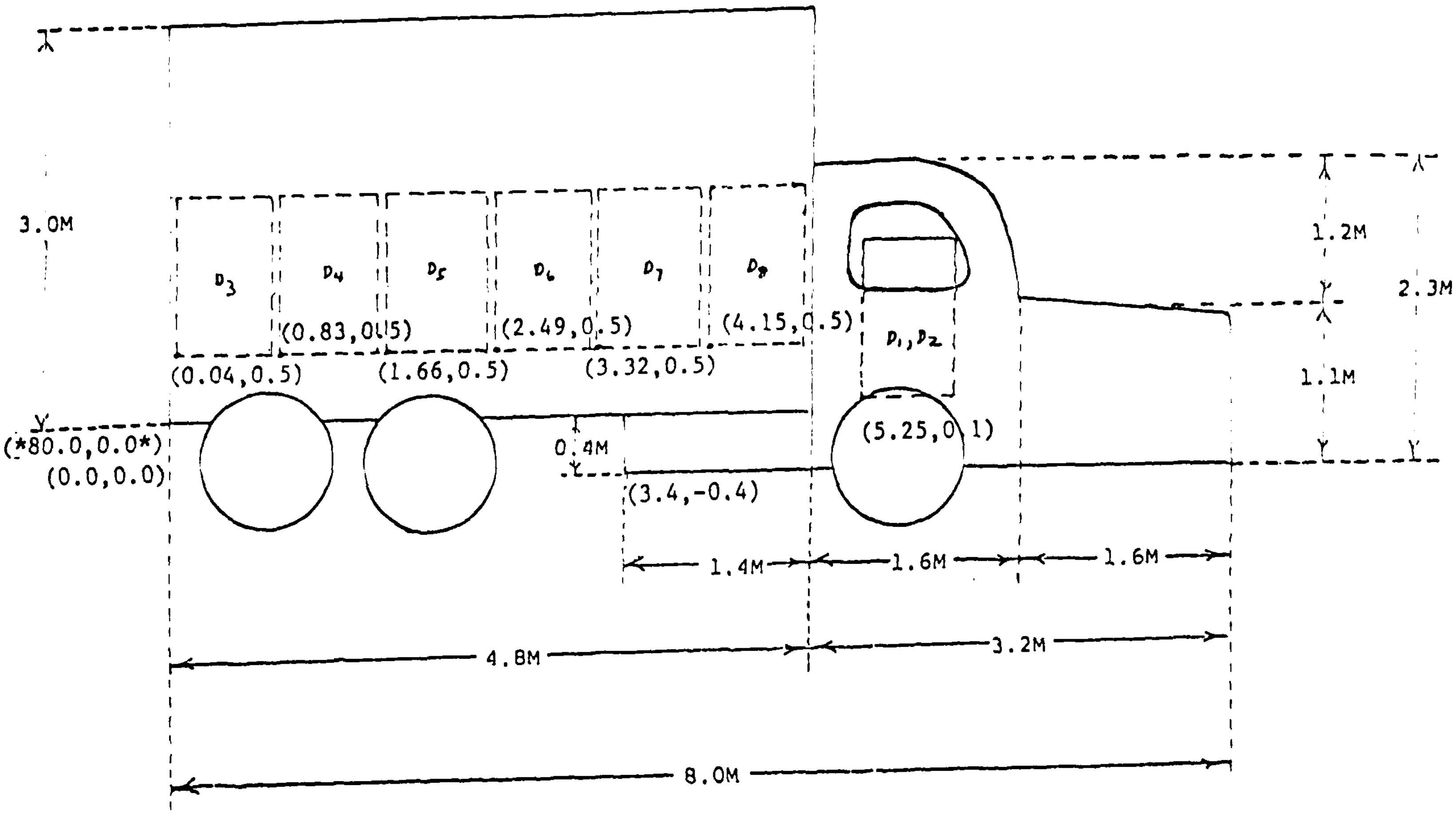


Figure 3.3 Defender Target Locations, Truck 2, Position 0

Truck 3
Just Prior to Mine Detonation

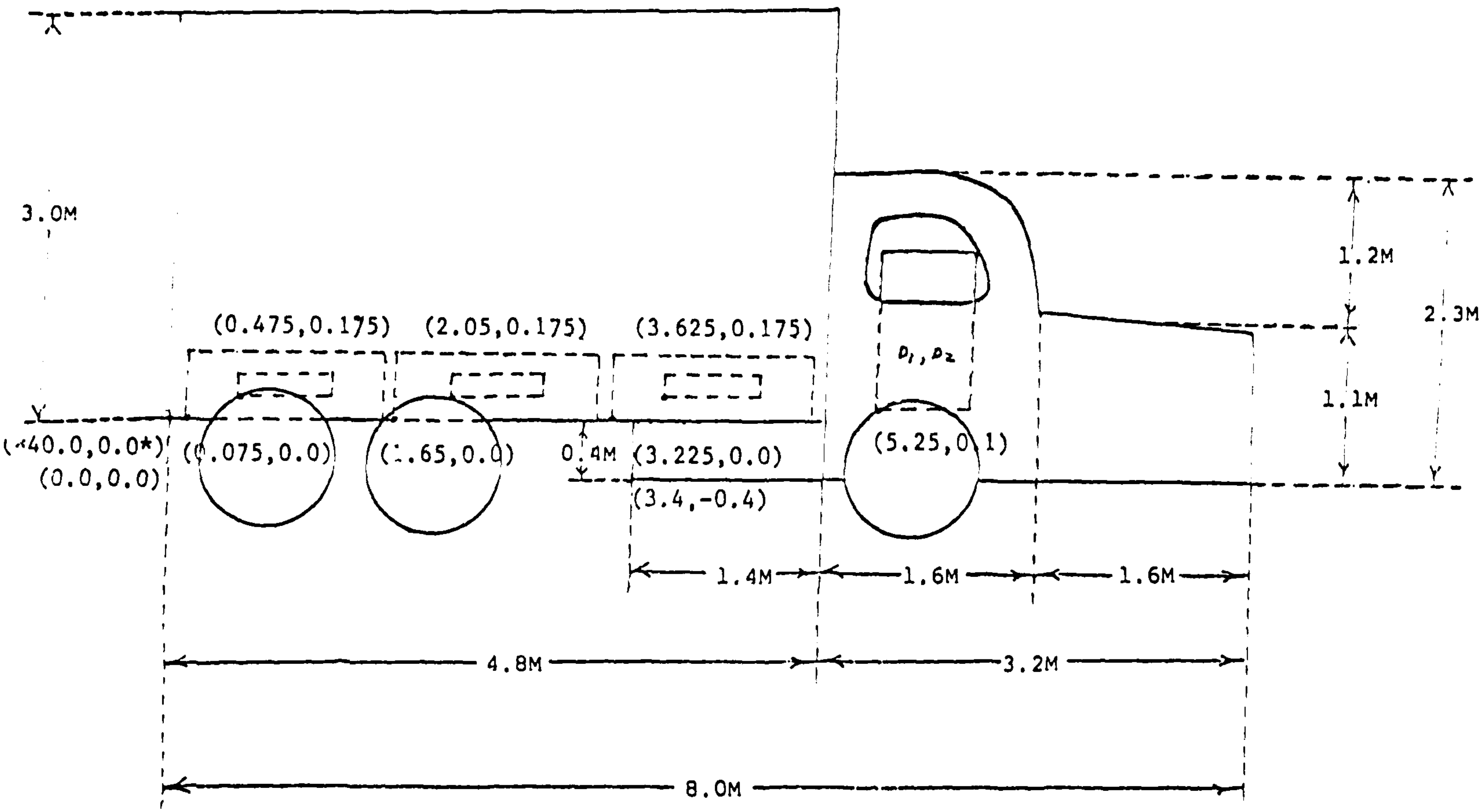


Figure 3.4 Defender Target Locations, Truck 3, Position 0

Truck 4

Just Prior to Mine Detonation

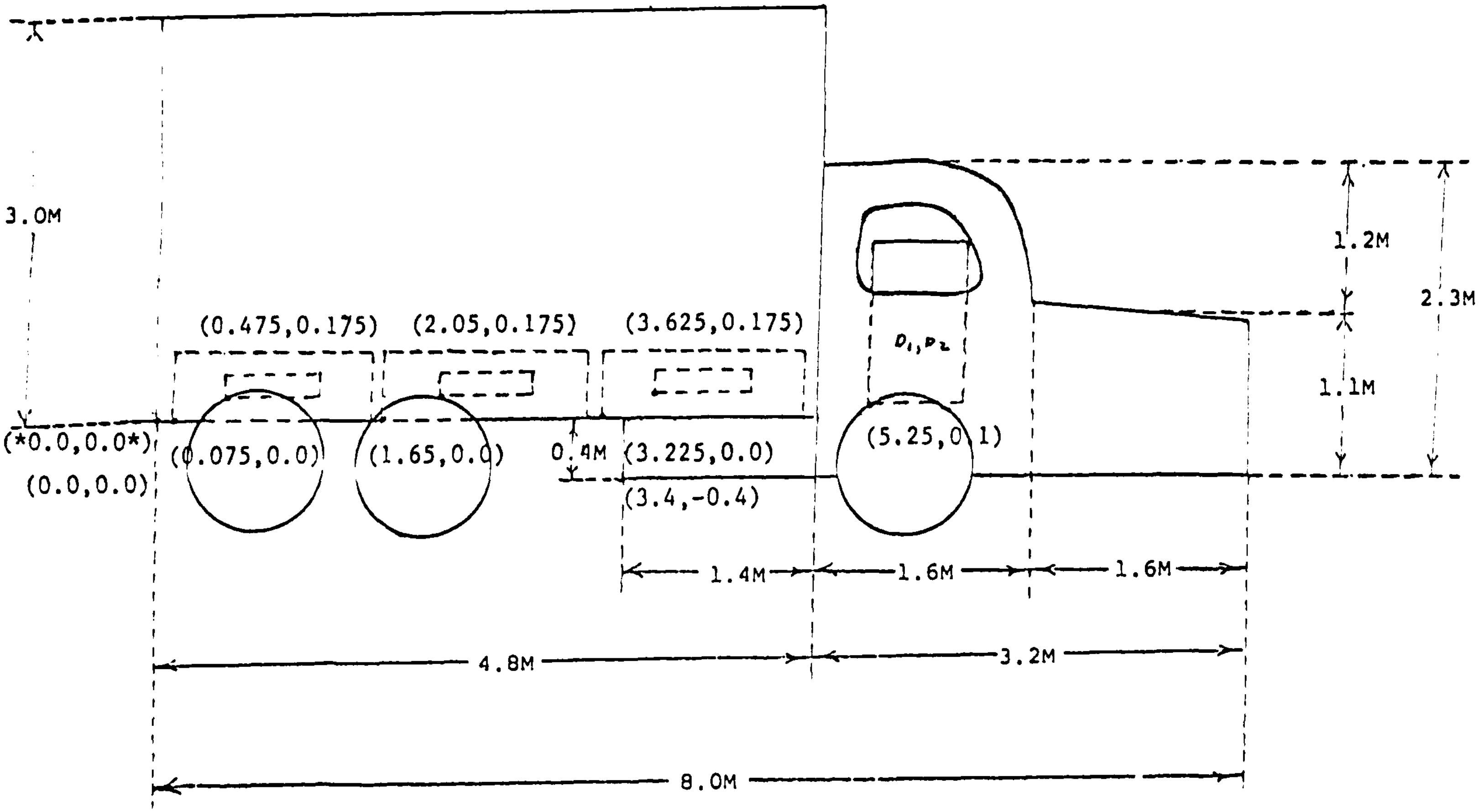


Figure 3.5 Defender Target Locations, Truck 4, Position 0

Truck 1
Moving State

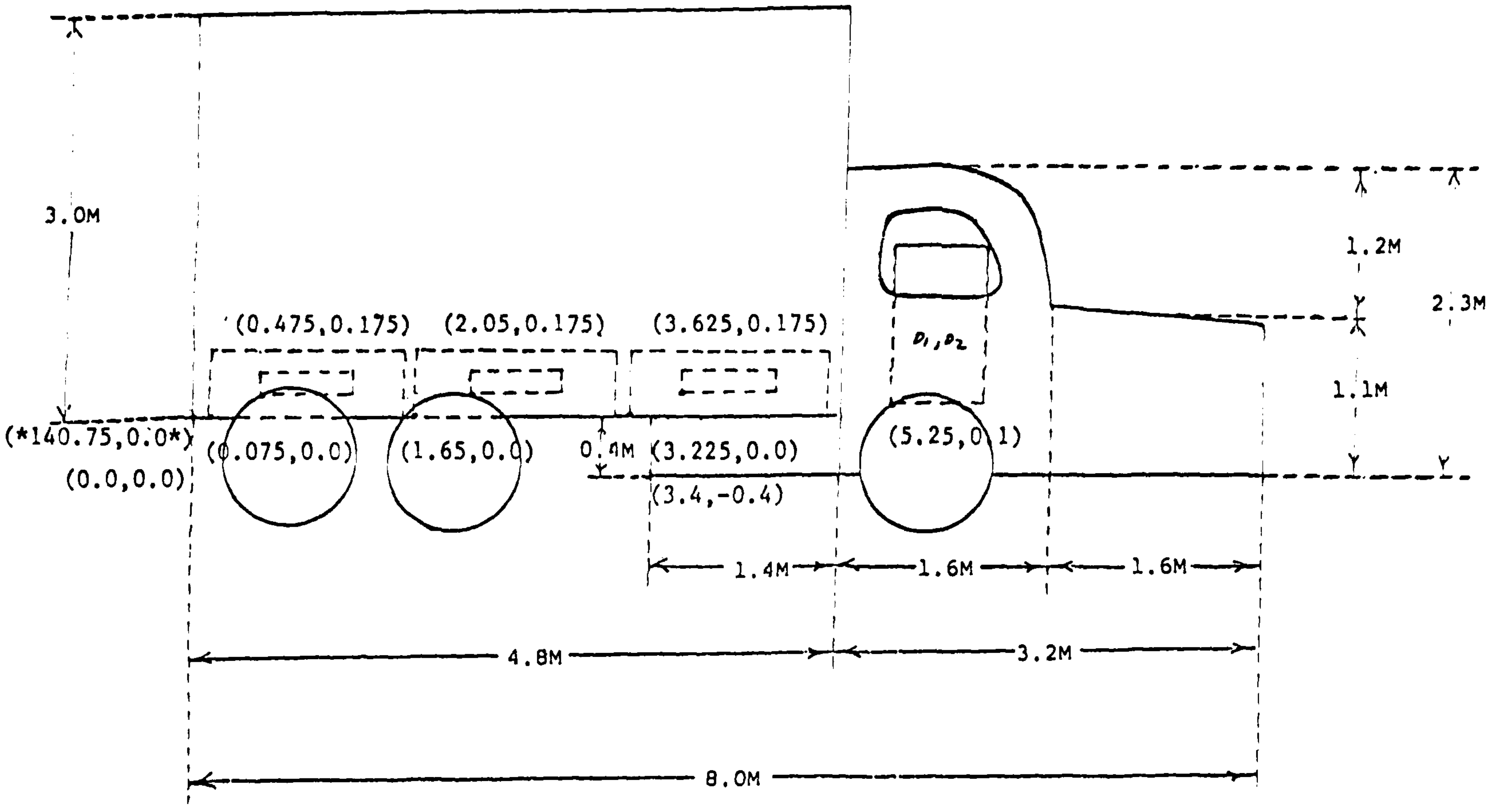


Figure 3.6 Defender Target Locations, Truck 1, Position 1

Truck 2
Moving State

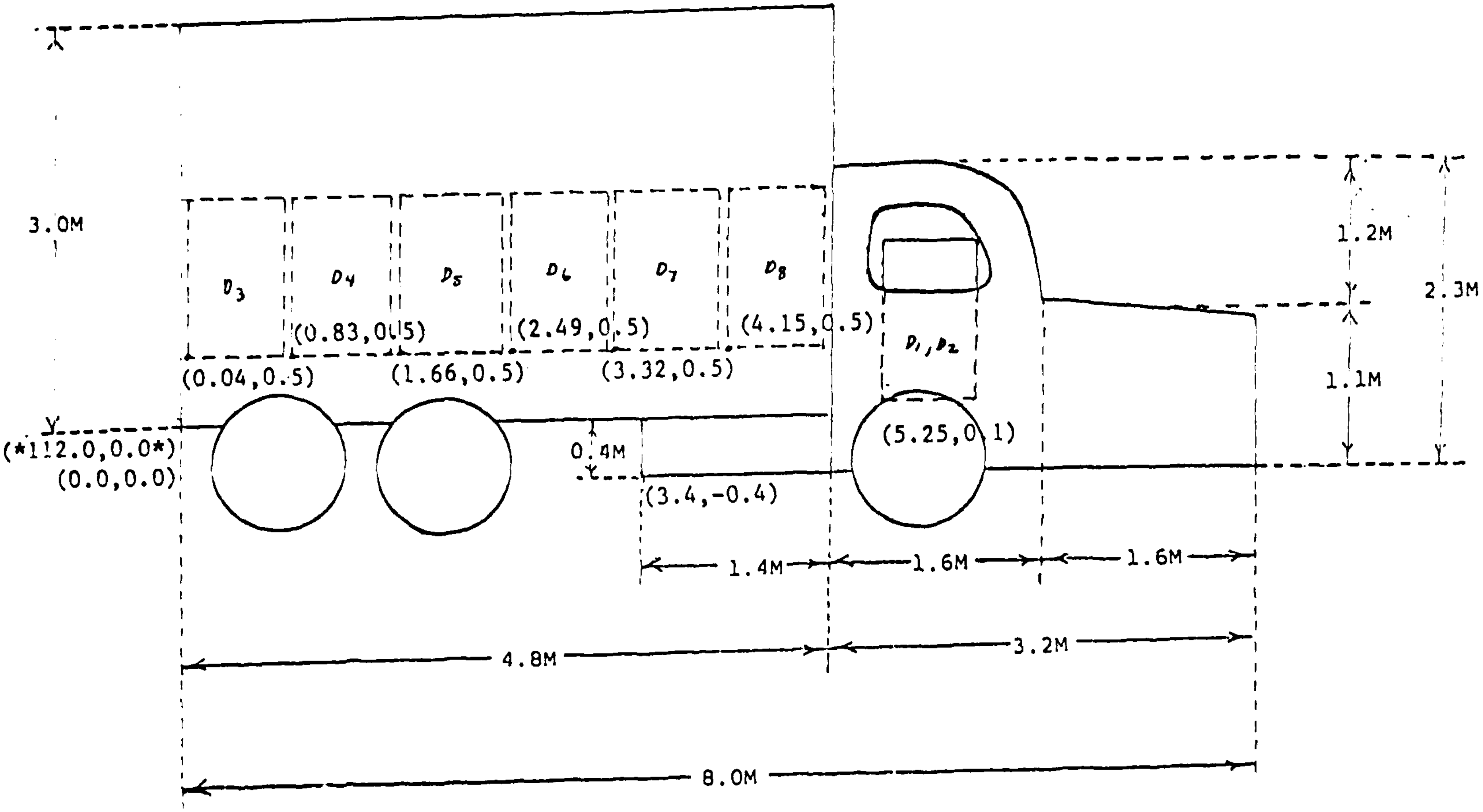


Figure 3.7 Defender Target Locations, Truck 2, Position 1

Truck 3
Moving State

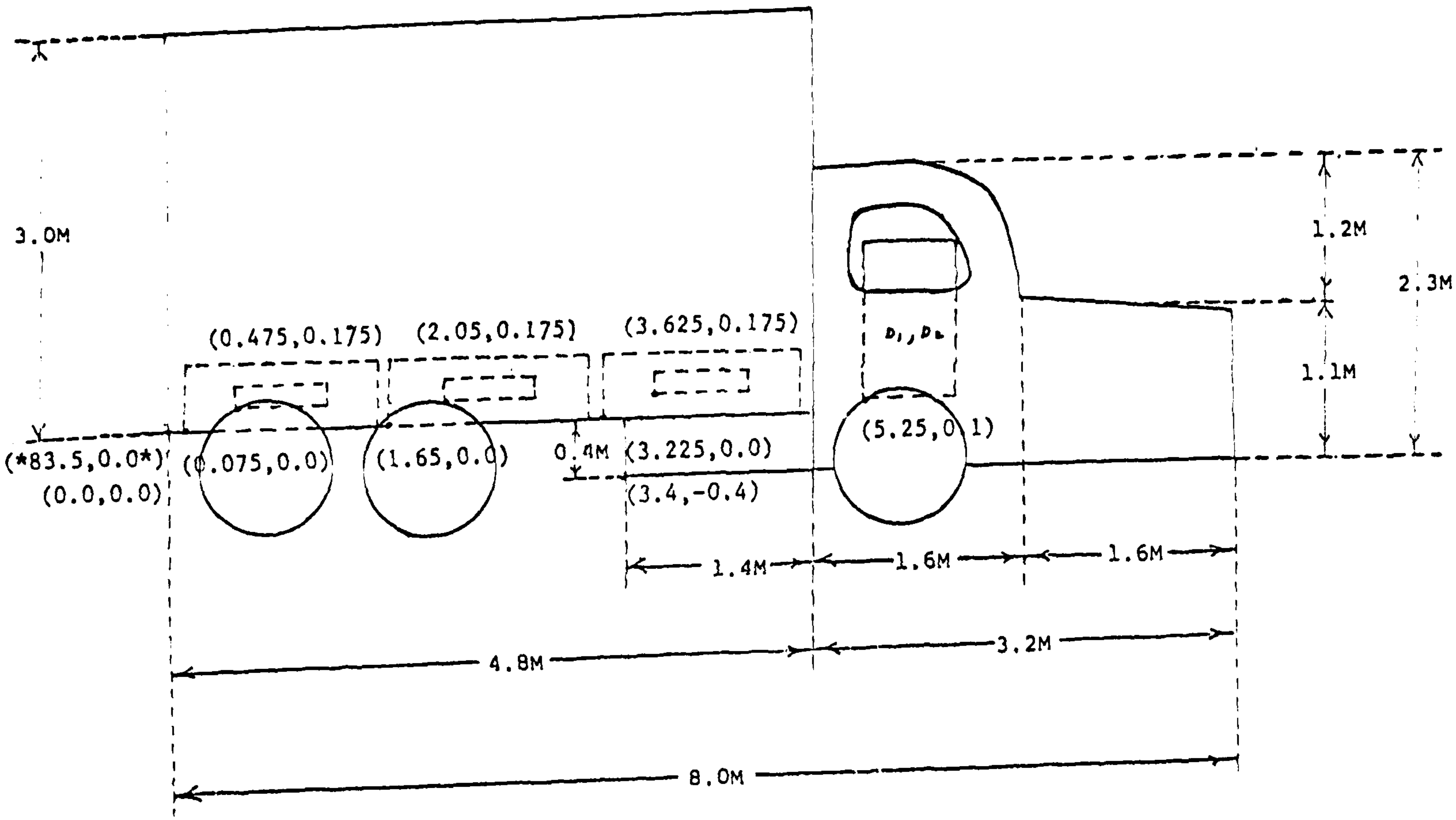


Figure 3.8 Defender Target Locations, Truck 3, Position 1

Truck 4
Moving State

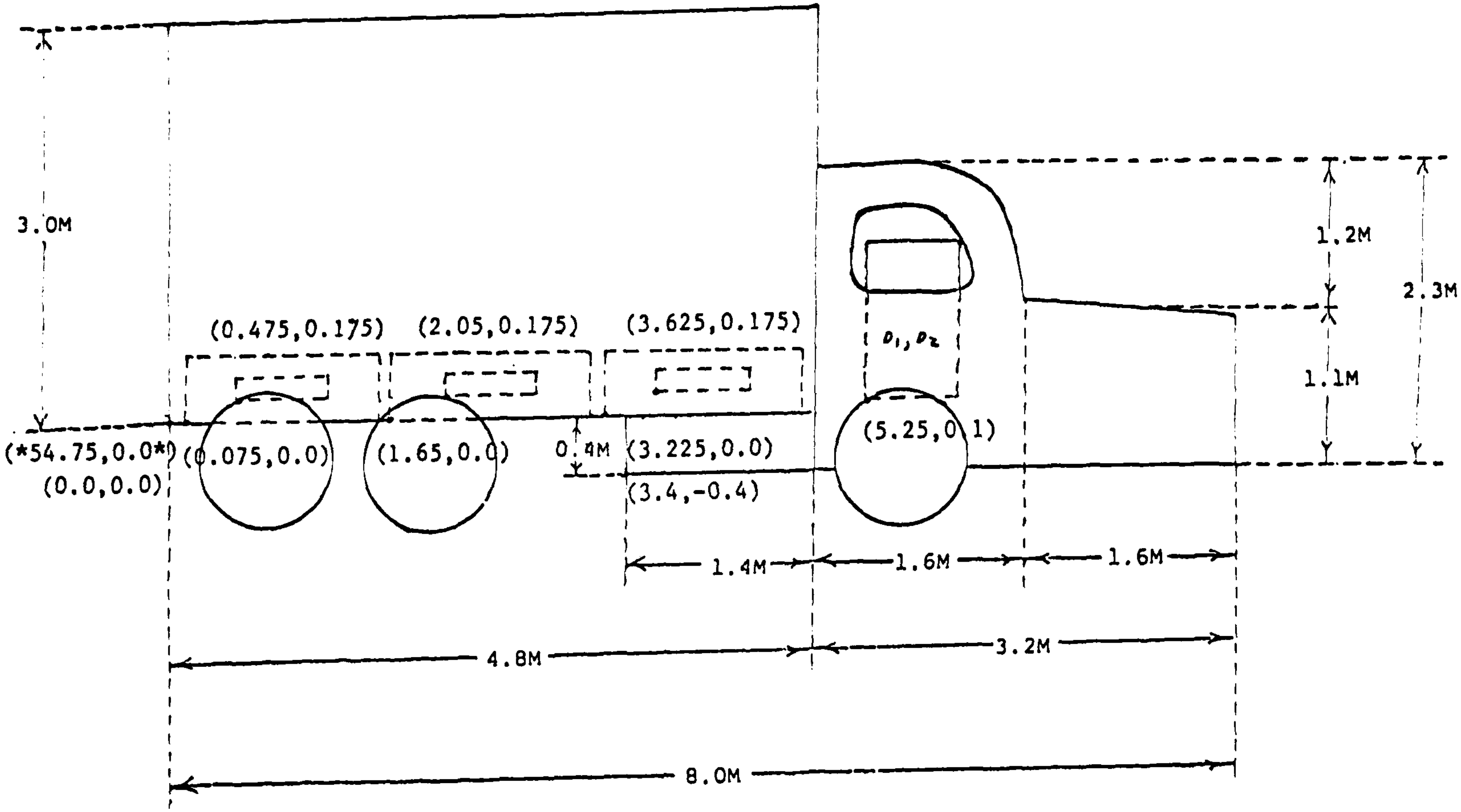


Figure 3.9 Defender Target Locations, Truck 4, Position 1

Truck 1
Stopped State

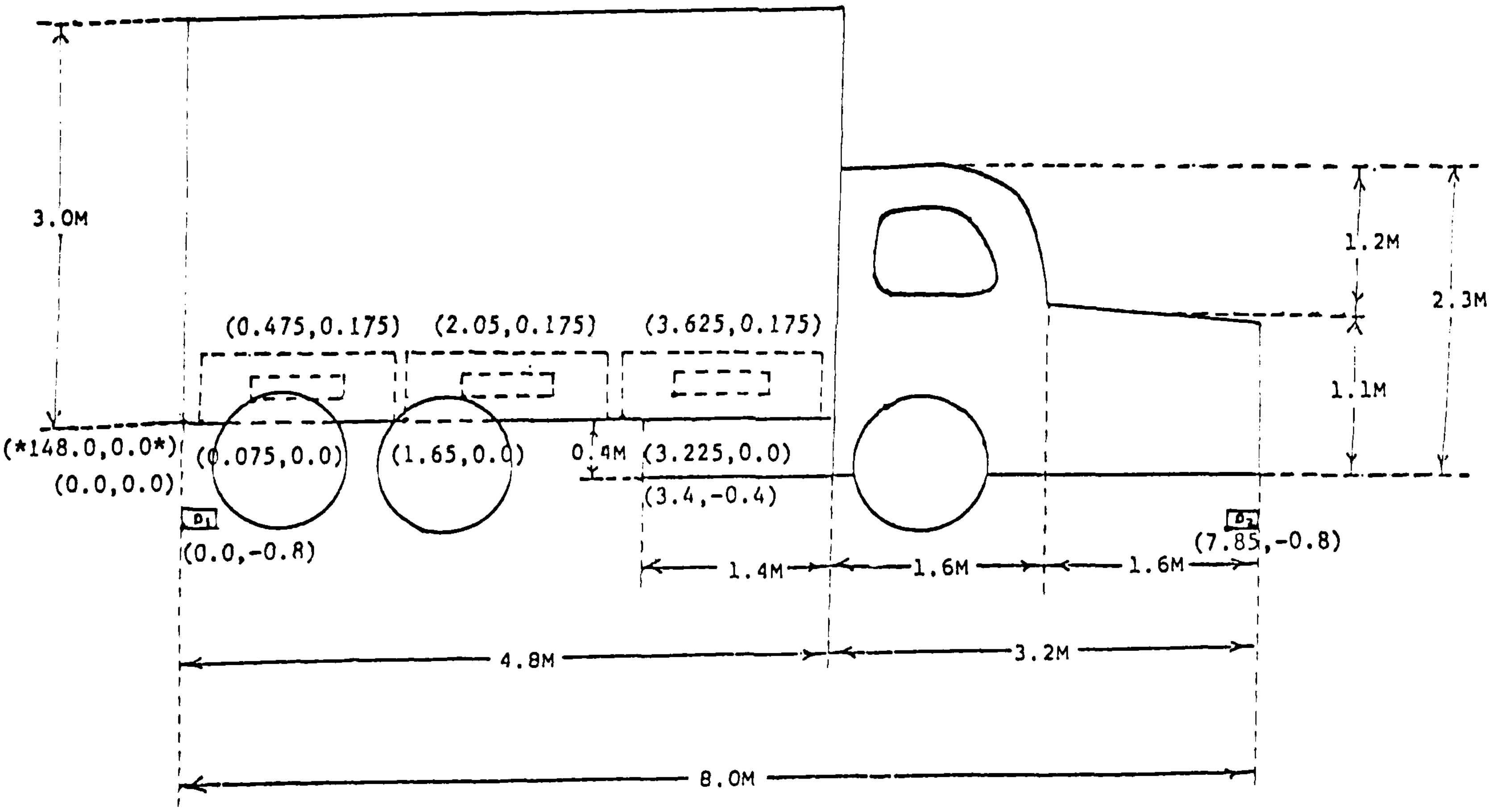


Figure 3.10 Defender Target Locations, Truck 1, Position 2

Truck 2
Stopped State

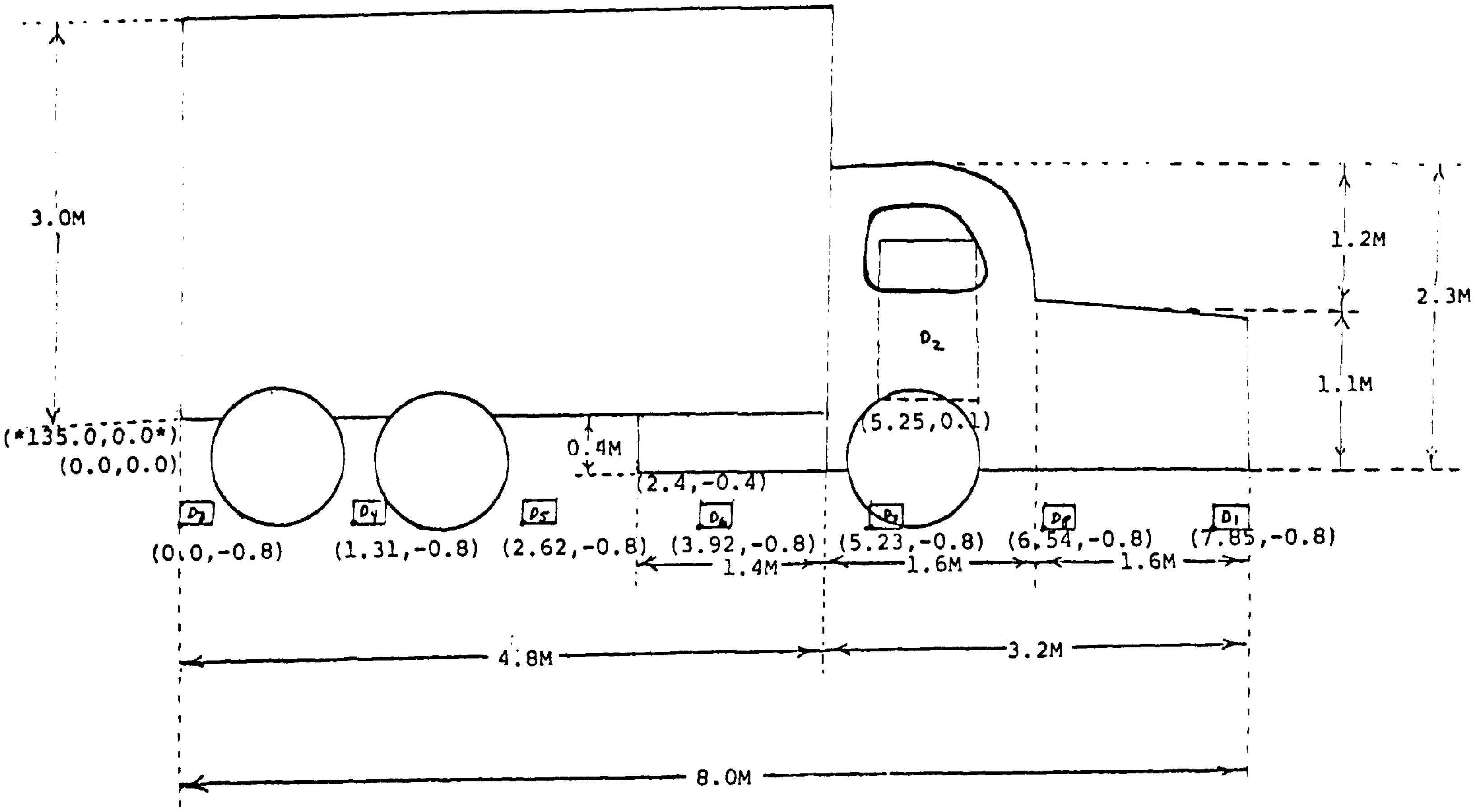


Figure 3.11 Defender Target Locations, Truck 2, Position 2

Truck 3
Stopped State

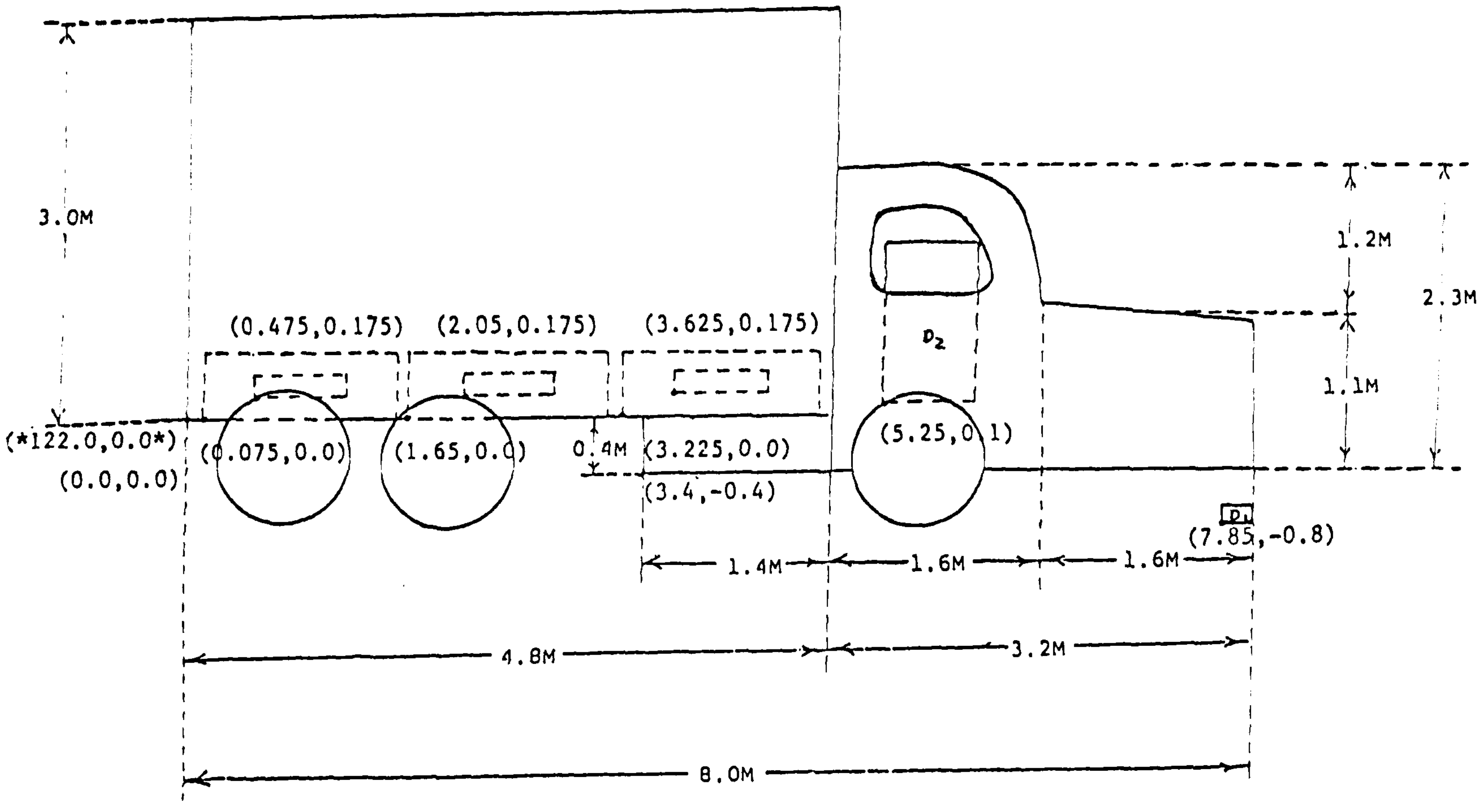


Figure 3.12 Defender Target Locations, Truck 3, Position 2

Truck 4
Stopped State

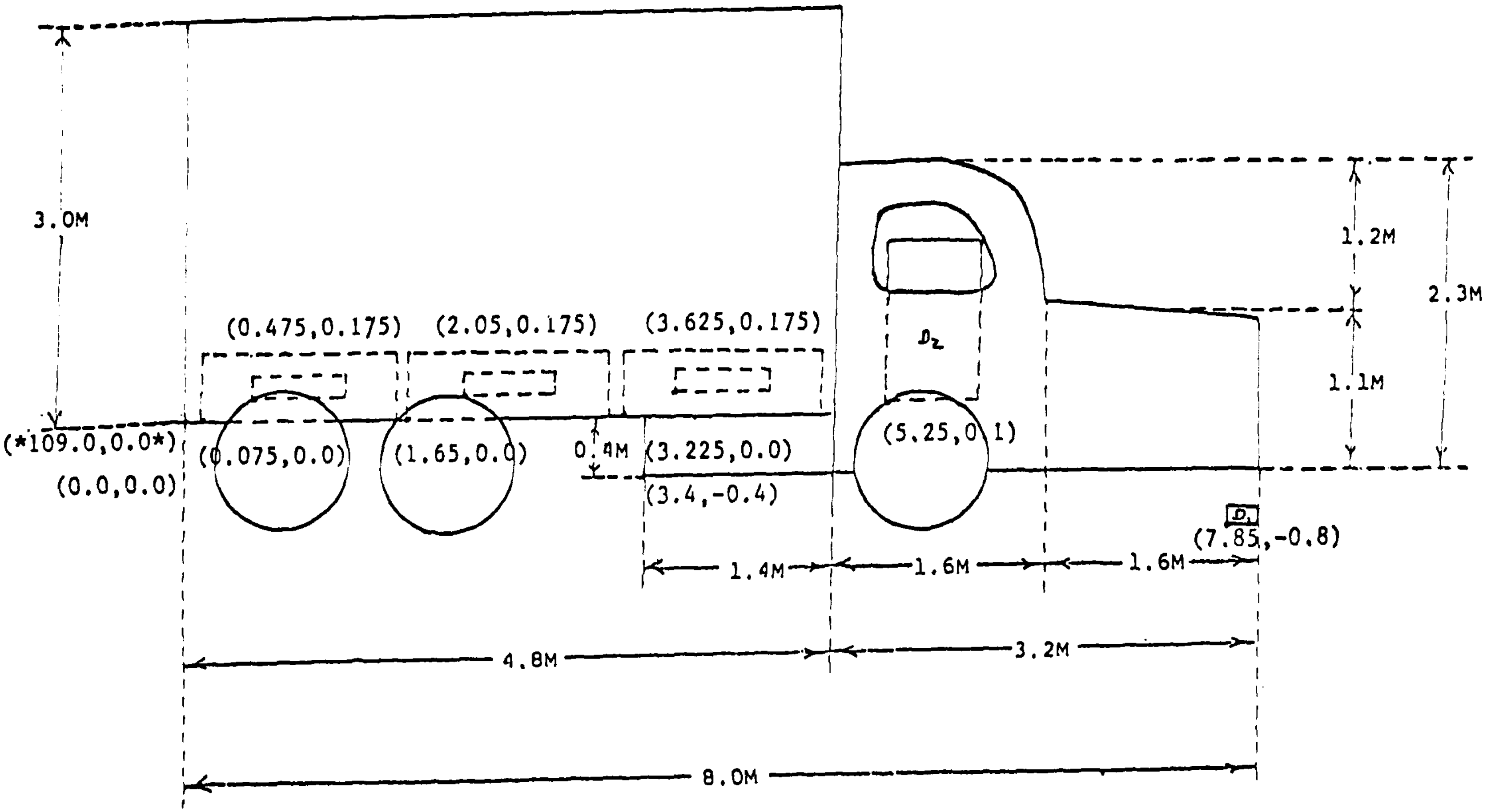


Figure 3.13 Defender Target Locations, Truck 4, Position 2

direct fire from the security defensive personnel. It is assumed that roughly 0.02 square meters of each attacker's body is exposed to direct fire, modeled as a square target measuring 0.125 meters on each side. Refer to Figure 3.14 for size and location of attack force members. A particular attack force member is identified by the character 'A' followed by the number of the attacker. A1, for example, is used to refer to the attack force member 1.

3.2.4 Vehicle Assumptions

Detailed dimensions of each vehicle involved in the stand-off attack simulation are given in Figures 3.2-3.13. All vehicles involved are assumed to be canvas-covered flatbed stake trucks. Each truck is 8.0 meters in total length. The engine section of each vehicle measures 1.1 meters in height by 1.6 meters in width. Vehicles are assumed destroyed if hit by an RPG in the engine section, or by fire if the fuel tank is ignited. The cab section of each vehicle is assumed to measure 2.3 meters in height by 1.6 meters wide. The canvas-covered rear section of each vehicle is modeled as a rectangle 4.8 meters long and 3.0 meters high. The fuel tank is located directly behind the vehicle cab below the truck bed. The fuel tank is also modeled as a rectangular target measuring 0.4 meters high by 1.4 meters in length.

Vehicle engine areas are denoted by 'ET' followed by the truck number. For example, ET1 is used to refer to the engine area of Truck 1. The rear section of the canvas-covered truck is uniquely refered to by 'CT' followed by the truck number. Thus, CT1 would be used to identify the canvas-covered rear section of Truck 1. Vehicle fuel tanks are denoted by 'GT' followed by the truck number. GT1 is used to refer to the fuel tank on Truck 1.

3.2.5 Vehicle Movement Assumptions

At the point of mine detonation, all convoy vehicles are assumed to be traveling at 40 KPH. Immediately after mine detonation, all vehicles decelerate uniformly. The distance required for each vehicle to come to a complete halt was determined by subtracting the starting position (x coordinate value in Figures 3.2 through 3.5) from their stopped position (x coordinate value in Figures 3.10 through 3.13). The stopped positions were

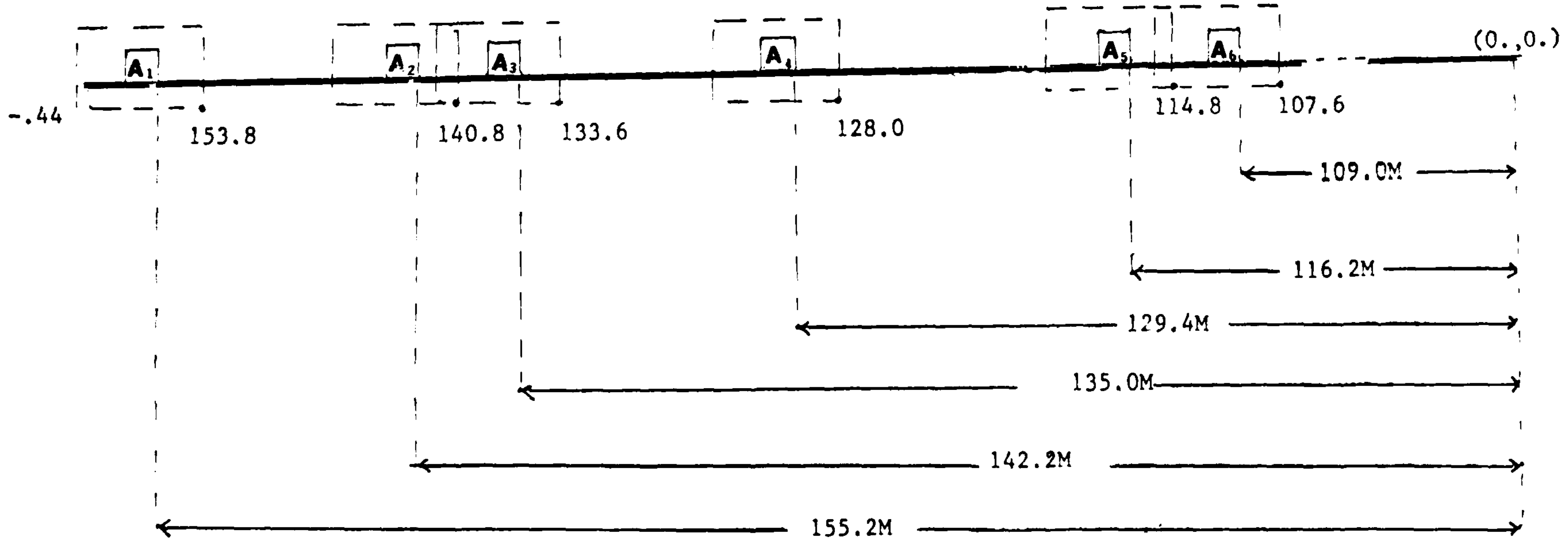


Figure 3.14 Attacker Target Locations

selected to provide a minimum of 5 meters separation between each vehicle. The distance for Truck 1 to come to a complete stop is 148 - 120 = 28 meters, for example. Assuming each truck decelerates uniformly, it is possible to calculate average positions of each vehicle. Truck 1, which is closest to the mine detonation is assumed to stop in 5 seconds. The last vehicle, Truck 4, is assumed to require 10 seconds. The other two vehicles are evenly spaced over the 5-10 second interval. Truck 2 is assumed to stop in 6.67 seconds, and Truck 3 is assumed to stop in 8.33 seconds.

The location of each truck after mine detonation is then given by the expression:

$$x(t) = x(o) + v(o)t - 1/2\ at^2$$

where:

$x(t)$ = location of truck in meters from origin (along x axis)

$x(o)$ = initial truck position in meters from origin (along x axis)

$v(o)$ = initial truck velocity in meters/second (40 KPH = 11 meters/second)

a = constant value of *deceleration* in meters/second^2

t = time elapsed since mine detonation in seconds.

The location of each vehicle when stopped is given by:

$$x(t_s) = x(o) + v(o)t_s + 1/2\ at_s$$

where:

$x(t_s)$ = location of truck when stopped measured from the origin along the x axis

t_s = time required for truck to stop (point when $v(t) = 0.$)

Because the deceleration of each truck is constant, it is possible to solve for "a" in each expression and set the resulting expressions equal:

$$a = 2/t^2\ x(t) - x(0) - v(0)t\ ,$$

$$a = 2/t^2\ x(t_s) - x(0) - v(0)t_s.$$

Thus,

$$2/t^2\ x(t) - x(0) - v(0)t\ = 2/t_s^2\ x(t_s) - x(0) - v(0)t_s$$

or

$$x(t) = x(0) + v(0)t + x\left[t_s - x(0) - v(0)t_s\right]\left[t/t_s\right]^2.$$

The average position of each truck is determined at time $t = t_s/2$ in that deceleration is constant.

For example, the average position of Truck 1, x_1, is then given by:

$$x_1 = 120. + 11(5./2) + \left[148 - 120 - 11(5.)\right]\left[\frac{5/2}{5}\right]^2$$

$$= 140.75 \text{ meters.}$$

Figure 3.15 illustrates the location of all trucks in terms of distance from the origin along the x axis in meters varying with time from mine detonation. For analysis purposes, the average truck positions will be used during the period when the trucks are decelerating.

3.2.6 Weapon Assumptions

Nuclear weapon projectiles are assumed to have a cross sectional area of 0.105 meters, which, if hit by either automatic weapon fire or RPG fire, will result in damage or destruction. The cross-sectional area resulting in destruction was assumed to be 0.15 meters high by 0.7 meters wide. Each weapon-carrying vehicle is loaded with three nuclear projectiles. The projectiles/containers are secured in the center of the truck bed, arranged in a linear fashion equally spaced over the bed length.

Standard containers were placed around weapons which, if hit by rifle fire outside the dimensions of the nuclear round, would cause the weapons within the container to be rejected, pending a detailed inspection and certification process. Components such as the fuzing and arming mechanisms would be included within the weapon container target. Each container was assumed to contain one nuclear weapon. Container targets with associateo damage and destruction hit regions are shown in Figures 3.10-3.13. Each container is assumed to be 0.5 meters high and 1.5 meters long.

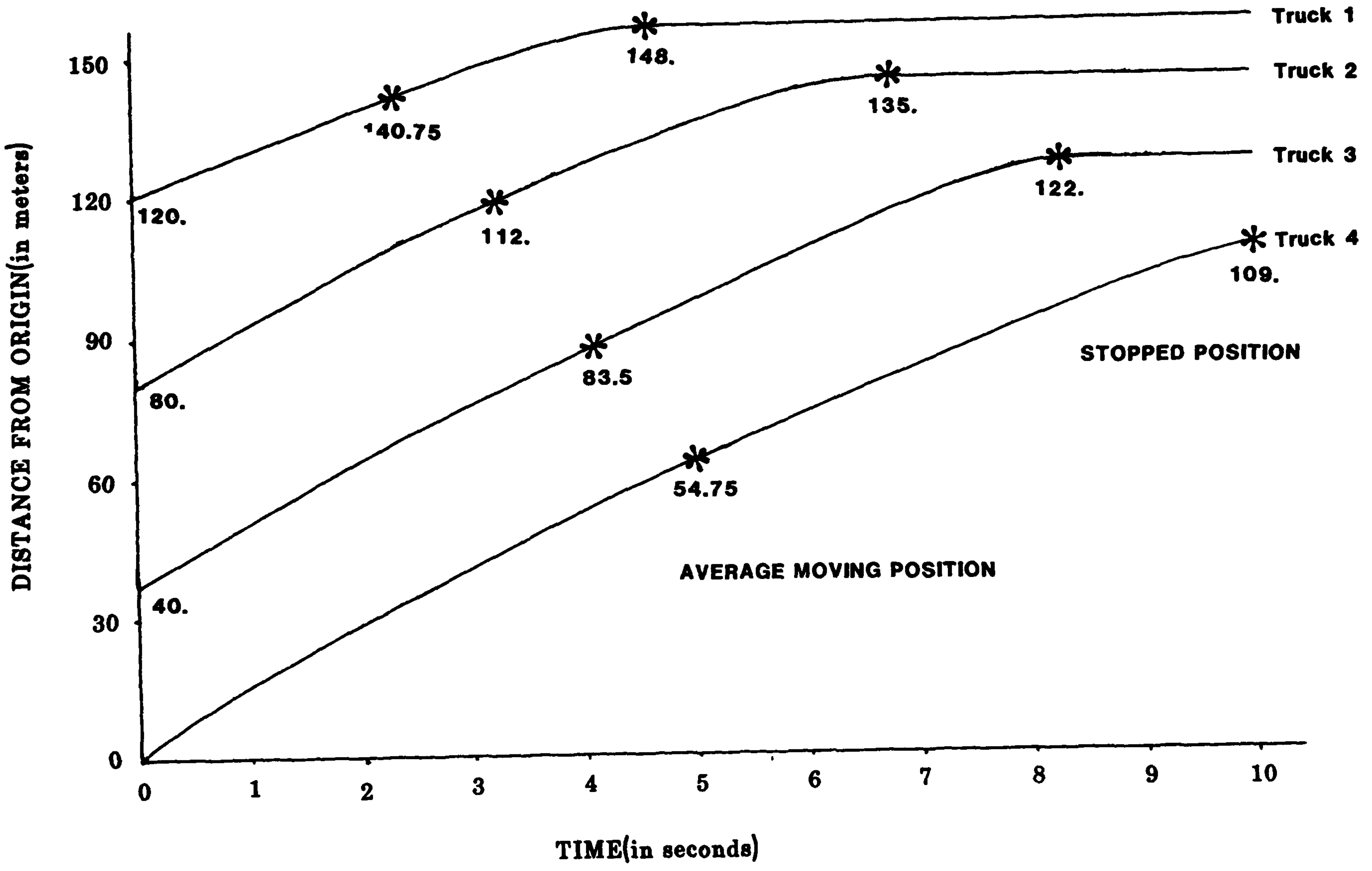


Figure 3.15 Truck Locations Versus Elapsed Time After Mine Detonation

The weapon area resulting in destruction if hit is denoted by the weapon number followed by the truck number. W1T1 is used to refer to Weapon 1, Truck 1, for example. A particular weapon container is denoted by the container number followed by the truck number: K1T1 is used to refer to Weapon Container 1, Truck 1. The average position of the weapons and weapon containers within moving vehicles (considered Position 1) is shown in Figures 3.6 through 3.9. The position of weapons and weapon containers within stopped vehicles (considered Position 2) is shown in Figures 3.10 through 3.13. The second position of all targets is denoted by adding 'P2' to the end of their unique three or four character designation. Thus, K1T1P2 is used to refer to Container 1, Truck 1, position 2, for example. Character designators without the P2 suffix refer to targets in Position 1.

3.2.7 Defender Strategy Assumptions

Once the convoy is aware of the attack, an attempt will be made to continue with the convoy movement and push through the ambush area. However, by scenario definition, the roadway is completely blocked by the mined vehicle and debris generated from the initial mine detonation. As the vehicles decelerate, the assistant drivers are assumed to be the only defensive personnel capable of immediate response. Each assistant driver will direct counter fire at the source of received automatic weapons fire (attackers designated numbers 3 and 6). After both attackers with automatic weapons are defeated, defensive fire will be directed at attack force personnel having RPGs. After all vehicles have halted, defenders use trucks for cover and concentrate counterfire primarily on attackers with automatic weapons. When attackers possessing automatic weapons are defeated, fire will then be directed at the source of RPG fire (Attackers 1, 2, 4 and 5).

3.2.8 Attacker Strategy Assumptions

In general, Attackers numbered 1, 2, 4 and 5 attempt to destroy Trucks 1, 2, 3 and 4, respectively, by firing RPGs at the truck engines. After trucks have been stopped, the attackers use the RPGs to fire at rear sections of trucks, attempting to destroy either personnel or weapons. Attackers 3 and 6 attempt to eliminate defense personnel. Attacker 3 is assumed to concentrate fire on defense personnel in Trucks 1 and 2, while attacker 6 attempts to defeat security personnel in Trucks 3 and 4. Attackers 3 and 6 will place most emphasis on hitting both drivers and assistant drivers before firing at additional security force personnel in the rear section of Truck 2. Fire will not be directed at truck fuel tanks. The fuel tanks may be hit from indirect small arms fire, but will not be considered as primary targets.

3.2.9 Aim Point Assumptions

Aim Points Used by Attack Force. Attackers employing RPGs use the center of the forward engine section as ar. aim point when attempting vehicle destruction. The center of the rear canvas-covered truck bed is the aim point when trying to hit weapons or security force personnel. Attackers employing automatic weapons aim at the center of defender targets whenever those targets can be visually acquired. Security force personnel located in the rear section of the security vehicle cannot be seen directly. These personnel are therefore attacked by spraying the rear canvas-covered truck sections randomly with automatic weapon fire. After each vehicle has stopped and defenders have assumed defensive positions behind their vehicle, all defenders are modeled as fixed aim points.

Aim Points Used by Defense Force. Attackers are assumed to be concealed in brush and surrounding foliage. Identification of the exact location of the Special Operations Team members is therefore difficult. Key signatures are used such as sound, intermittent muzzle flashes, smoke, and movement to identify regions in which attackers are located. Defenders direct automatic weapon fire into those regions which they have identified as the sources of fire being received. Attackers remain in preselected positions throughout the 20 second duration of the force-on-force attack sequence.

3.2.10 Defense Force Weapon Assumptions

Drivers in each vehicle are armed with M16 rifles. The firing rate is established as 175 rounds per minute for the 20 second encounter, and is based upon an equal combination of semi- and fully-automatic firing modes. The time required to exchange magazines was also incorporated into this average firing rate. In addition to the drivers, two security guards in the rear section of Truck 2 are also armed with M16 rifles and are assigned the same firing rate.

Assistant drivers, or guards, and three security personnel in the rear section of Truck 2 are armed with M60 machine guns. A firing rate of 550 rounds per minute was used for this weapon. Selection of this firing rate was based on similar factors used to determine the firing rate used for the M16.

The remaining security force personnel in the rear section of Truck 2 are armed with the M79 grenade launcher. The M79 rate of fire is 15 rounds per minute. A lethal kill radius of 5 meters was established for each M79 round. Thus an attacker would be considered a casualty if the distance between the attacker and the point of detonation of the M79 round was less than or equal to 5 meters.

3.2.11 Attack Force Weapon Assumptions

Attackers 1 and 3 are armed with the AK47 rifle with an average firing rate of 200 rounds per minute. The remaining attackers are armed with an equivalent RPG weapon with firing rate of 5 rounds per minute. RPGs were assumed to be armor piercing weapons, effective for destruction of vehicles, should vehicles be hit in the forward engine section. RPGs were not modeled as having a lethal kill radius for personnel or weapons, because the canvas-covered rear section of the truck would not provide projectile detonation. Refer to Table 3.1 for a summary of weapon types and associated firing rates for weapons used for both the attack and defense forces in the simulation.

3.2.12 Attack and Defense Force Separation Distance Assumptions

For simplicity in simulation input, the defense force and attack force are assumed to reside in two parallel planes 75 meters apart. Thus, the minimum distance between and attacker and defender is 75 meters.

3.2.13 Aiming Error Assumptions

For purposes of this analysis, weapon accuracy was considered to be a rate. In addition to the drivers, two security guards in the rear section of Truck 2 are also armed with M16 rifles and are assigned the same firing rate.

Assistant drivers, or guards, and three security personnel in the rear section of Truck 2 are armed with M60 machine guns. A firing rate of 550 rounds per minute was used for this weapon. Selection of this firing rate was based on similar factors used to determine the firing rate used for the M16.

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3.2.11 Attack Force Weapon Assumptions

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3.2.12 Attack and Defense Force Separation Distance Assumptions

For simplicity in simulation input, the defense force and attack force are assumed to reside in two parallel planes 75 meters apart. Thus, the minimum distance between and attacker and defender is 75 meters.

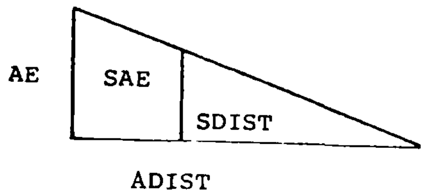
3.2.13 Aiming Error Assumptions

For purposes of this analysis, weapon accuracy was considered to be a function of:

- separation distance between the target and firer,
- velocity of the target, and
- aiming errors inherent in the particular weapon employed.

Environmental factors, such as wind, were not considered. Aiming error inherent to the particular type of weapon employed was determined from references, or selected based on expert opinion.

Any change in separation distance between the firer and target was assumed to effect the aiming error as a ratio of the total separation distance over the standard separation distance. The calculation of the modified aiming error, assuming the separation distance is more than 75 meters, can be illustrated by the following geometric figure.



AE (Aiming Error) at distance ADIST is given by: AE = SAE *ADIST/SDIST.

where: SDIST - Standard Separation Distance. Distance between firer and target used as a baseline reference.

SAE - Standard Aiming Error. Radius in which 1/2 of all shots fired are expected to land, assuming a distance between firer and target of SDIST.

ADIST - Actual Distance between target and firer.

AE - Aiming Error assuming distance between firer and target is ADIST.

The standard aiming error is expressed as a distance in meters. This distance defines the radius of a circle in which one-half of all rounds fired are expected to hit. The aiming error used for automatic weapons was 0.5 meters when the separation distance was 75 meters. Reference 1 indicates small variations in aiming error exist between the M16, AK47, and M60; however, ranges given for aiming error of these weapons significantly depends on the firer's training and environmental factors. The aiming error values for a separation distance of 75 meters were averaged for each automatic weapon type. The value of 0.5 meters was thus selected as representative.

Aiming error for the RPG and M79 were calculated as 1.12 meters and 15 meters, respectively, for a standard separation distance of 75 meters.

Due to the average target velocity of 20 KPH, an increase to the static aiming error by a factor of 1.5 was used. Table 3.1 summarizes the selected aiming errors associated with each weapon type for targets in a moving or static state.

Table 3.1 - WEAPON ASSUMPTIONS

Weapon Type	Target Velocity (KPH)	CEP (M)	Firing Rate (R/Min)
M16	0.	.5	175.
AK47	0.	.5	200.
M60	0.	.5	550.
50 Cal	0.	.5	550.
M79	0.	15.	15.
RPG	0.	1.12	5.
M19	0.	.5	450.
M16	20.	.75	175.
AK47	20.	.75	200.
M60	20.	.75	550.
50 Cal	20.	.75	550.
M79	20.	22.5	15.
RPG	20.	1.68	5.
M19	20.	.75	450.

3.3 INPUT DATA SUMMARY

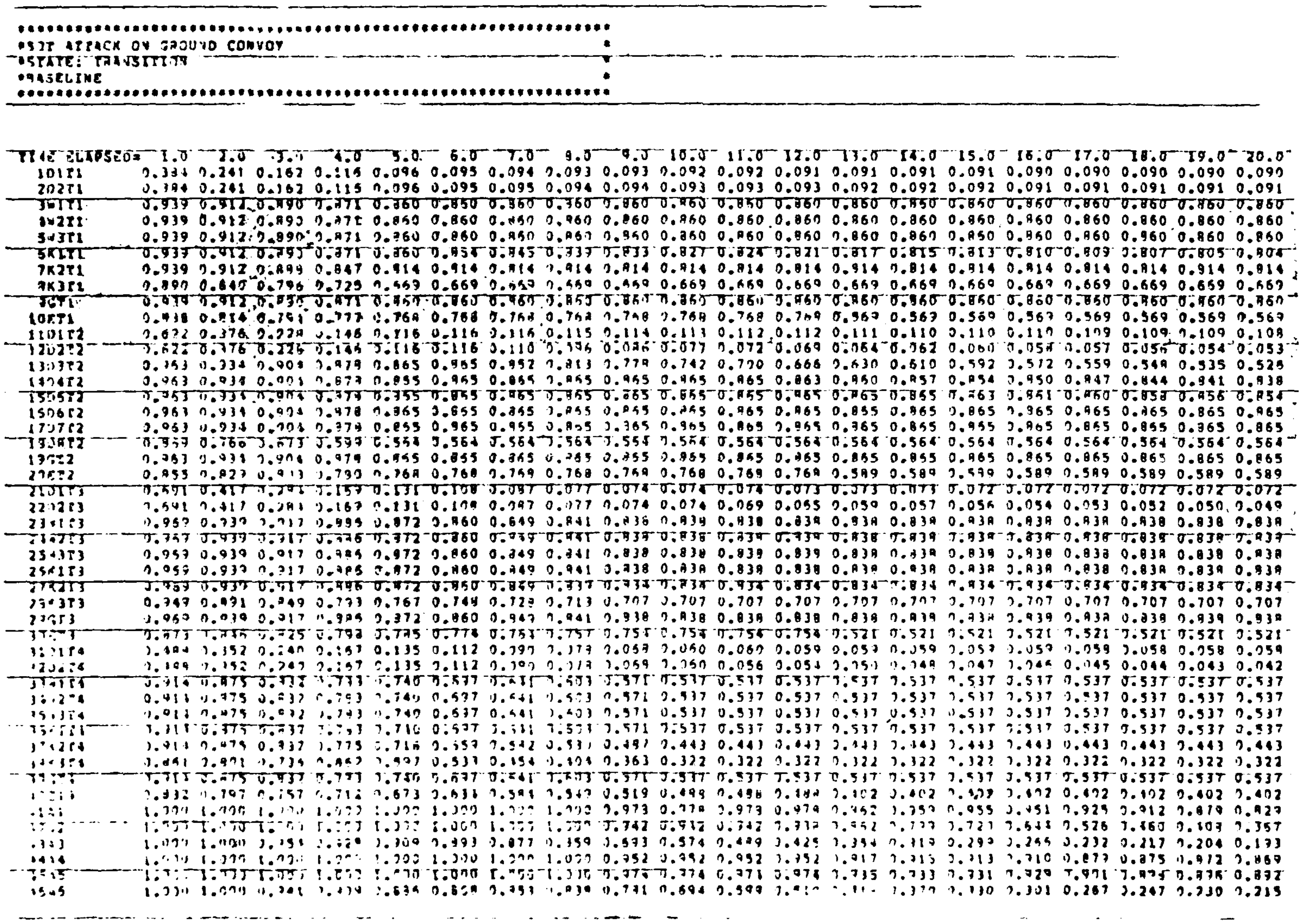
Refer to Appendix A for a complete listing of input data used to simulate the scenario previously described. Standardized data forms which aid in organizing the large amount of simulation input data are also included in Appendix A. These forms help insure that all information required for the simulation has been obtained. After the forms have been completed, the model is executed and form information entered interactively in the same order that it was originally written on the forms. Thus, by using the standardized data forms, an analyst having a minimum amount of prior computer experience may be able to perform a SAS simulation.

3.4 SAS OUTPUT

Output from the SAS model consists of probabilities that a particular target will still exist after a fixed amount of time has elapsed from the beginning of the simulation. Figure 3.16 shows a typical SAS output listing for the analysis of the baseline ground convoy scenario described in detail earlier in this section. Across the top of the output listing is time elapsed in seconds from the beginning of the simulation. Output is printed each second for the first 20 seconds into the simulation. All targets are listed in the column nearest the left hand side of the page. The remaining information within the output listing gives the probability that each target exists after a given amount of time has elapsed. The following information is supplied to help correlate the targets appearing on the left hand column of the ouput listing with those mentioned in the report previously:

D represents defender,
A represents attacker,
W represents weapon (critical component),
K represents weapon casing and container,
G represents gas tank or fuel tank,
E represents engine,
T represents truck.

The first number on the far left is the target number, and numbers



```
*************************************************************
*SJT ATTACK ON GROUND CONVOY                                *
*STATE: TRANSITION                                          *
*BASELINE                                                   *
*************************************************************

TIME ELAPSED=  1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0  13.0  14.0  15.0  16.0  17.0  18.0  19.0  20.0
   1D1T1     0.334 0.241 0.162 0.116 0.096 0.095 0.094 0.093 0.093 0.092 0.092 0.091 0.091 0.091 0.091 0.090 0.090 0.090 0.090 0.090
   2D2T1     0.384 0.241 0.162 0.115 0.096 0.095 0.095 0.094 0.094 0.093 0.093 0.093 0.092 0.092 0.092 0.091 0.091 0.091 0.091 0.091
   3W1T1     0.939 0.912 0.890 0.871 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860
   4W2T1     0.939 0.912 0.890 0.871 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860
   5W3T1     0.939 0.912 0.890 0.871 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860
   6K1T1     0.939 0.912 0.893 0.871 0.860 0.854 0.845 0.839 0.833 0.827 0.824 0.821 0.817 0.815 0.813 0.810 0.809 0.807 0.805 0.804
   7K2T1     0.939 0.912 0.899 0.847 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814 0.814
   8K3T1     0.890 0.840 0.796 0.725 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.669 0.659 0.669
   9CT1      0.939 0.912 0.895 0.871 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860 0.860
  10RT1      0.938 0.814 0.751 0.777 0.768 0.768 0.768 0.768 0.768 0.768 0.768 0.769 0.569 0.569 0.569 0.569 0.569 0.569 0.569 0.569
  11D1T2     0.622 0.376 0.228 0.146 0.116 0.116 0.116 0.115 0.114 0.113 0.112 0.112 0.111 0.110 0.110 0.110 0.109 0.109 0.109 0.108
  12D2T2     0.622 0.376 0.226 0.146 0.116 0.116 0.110 0.096 0.086 0.077 0.072 0.069 0.064 0.062 0.060 0.058 0.057 0.056 0.054 0.053
  13D3T2     0.963 0.934 0.904 0.879 0.865 0.865 0.852 0.813 0.779 0.742 0.720 0.666 0.630 0.610 0.592 0.572 0.559 0.548 0.535 0.526
  14D4T2     0.963 0.934 0.901 0.873 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.863 0.860 0.857 0.854 0.850 0.847 0.844 0.841 0.838
  15D5T2     0.963 0.934 0.904 0.879 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.863 0.861 0.860 0.858 0.856 0.854
  16D6T2     0.963 0.934 0.904 0.878 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865
  17D7T2     0.963 0.934 0.904 0.879 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865
  18D8T2     0.959 0.766 0.673 0.599 0.564 0.564 0.564 0.563 0.554 0.564 0.564 0.564 0.564 0.564 0.564 0.564 0.564 0.564 0.564 0.564
  19CT2      0.963 0.934 0.904 0.879 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865 0.865
  20RT2      0.855 0.827 0.813 0.790 0.768 0.768 0.769 0.768 0.769 0.768 0.769 0.769 0.589 0.589 0.589 0.589 0.589 0.589 0.589 0.589
  21D1T3     0.591 0.417 0.281 0.159 0.131 0.108 0.087 0.077 0.074 0.074 0.074 0.073 0.073 0.073 0.072 0.072 0.072 0.072 0.072 0.072
  22D2T3     0.591 0.417 0.281 0.167 0.131 0.108 0.087 0.077 0.074 0.074 0.069 0.065 0.059 0.057 0.056 0.054 0.053 0.052 0.050 0.049
  23W1T3     0.959 0.939 0.917 0.895 0.872 0.860 0.849 0.841 0.836 0.839 0.838 0.838 0.838 0.838 0.838 0.838 0.838 0.838 0.838 0.838
  24W2T3     0.959 0.939 0.917 0.896 0.872 0.860 0.849 0.841 0.839 0.838 0.839 0.839 0.838 0.839 0.839 0.839 0.838 0.839 0.838 0.839
  25W3T3     0.959 0.939 0.917 0.895 0.872 0.860 0.849 0.841 0.838 0.838 0.839 0.839 0.838 0.838 0.839 0.838 0.838 0.838 0.838 0.838
  26K1T3     0.959 0.939 0.917 0.895 0.872 0.860 0.849 0.841 0.838 0.838 0.839 0.838 0.838 0.838 0.838 0.838 0.838 0.838 0.838 0.838
  27K2T3     0.959 0.939 0.917 0.896 0.872 0.850 0.849 0.837 0.834 0.834 0.834 0.834 0.834 0.834 0.834 0.834 0.834 0.834 0.834 0.834
  28K3T3     0.949 0.891 0.849 0.793 0.767 0.749 0.729 0.713 0.707 0.707 0.707 0.707 0.707 0.707 0.707 0.707 0.707 0.707 0.707 0.707
  29CT3      0.959 0.939 0.917 0.895 0.872 0.860 0.849 0.841 0.838 0.838 0.838 0.838 0.838 0.839 0.838 0.839 0.838 0.838 0.839 0.838
  30RT3      0.873 0.836 0.825 0.798 0.785 0.778 0.753 0.757 0.754 0.754 0.754 0.754 0.521 0.521 0.521 0.521 0.521 0.521 0.521 0.521
  31D1T4     0.484 0.352 0.240 0.167 0.135 0.112 0.097 0.079 0.058 0.060 0.060 0.059 0.059 0.059 0.059 0.059 0.059 0.058 0.058 0.059
  32D2T4     0.499 0.352 0.247 0.167 0.135 0.112 0.090 0.078 0.059 0.060 0.056 0.054 0.050 0.048 0.047 0.046 0.045 0.044 0.043 0.042
  33W1T4     0.914 0.875 0.832 0.733 0.740 0.577 0.611 0.603 0.571 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537
  34W2T4     0.911 0.875 0.832 0.793 0.749 0.697 0.641 0.603 0.571 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537
  35W3T4     0.911 0.875 0.832 0.793 0.749 0.637 0.641 0.603 0.571 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537
  36K1T4     0.911 0.875 0.837 0.793 0.710 0.697 0.611 0.573 0.571 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537
  37K2T4     0.914 0.875 0.837 0.775 0.716 0.659 0.542 0.537 0.487 0.443 0.441 0.443 0.443 0.443 0.443 0.443 0.443 0.443 0.443 0.443
  38K3T4     0.861 0.891 0.734 0.662 0.597 0.531 0.454 0.404 0.363 0.322 0.322 0.322 0.322 0.322 0.322 0.322 0.322 0.322 0.322 0.322
  39CT4      0.911 0.875 0.837 0.777 0.740 0.697 0.641 0.603 0.571 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537 0.537
  40RT4      0.932 0.797 0.757 0.712 0.673 0.631 0.591 0.547 0.519 0.498 0.498 0.488 0.402 0.402 0.409 0.402 0.402 0.402 0.402 0.402
  1111       1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 0.973 0.778 0.973 0.979 0.962 0.959 0.955 0.951 0.925 0.912 0.879 0.829
  1212       1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 0.742 0.912 0.742 0.712 0.952 0.777 0.721 0.643 0.526 0.460 0.409 0.357
  1313       1.000 1.000 0.951 0.929 0.909 0.893 0.877 0.859 0.693 0.574 0.489 0.425 0.354 0.319 0.299 0.265 0.232 0.217 0.204 0.193
  1414       1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 0.952 0.952 0.952 0.952 0.917 0.915 0.913 0.910 0.877 0.875 0.872 0.869
  1515       1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 0.974 0.974 0.971 0.974 0.735 0.733 0.731 0.729 0.971 0.875 0.876 0.892
  1545       1.000 1.000 0.941 0.419 0.634 0.858 0.853 0.838 0.731 0.694 0.599 0.512 [illegible] 0.379 0.330 0.301 0.267 0.247 0.230 0.215
```

Figure 3.16 SAS Output Showing Probability Targets Exist With Time

following characters denote the specific target. For example, target number 18, which is given by D8T2, represents Defender(D) 8 on Truck(T) 2.

Figure 3.17 (a and b) shows the conditional probability that a given number of targets within a particular group remain undestroyed with time. The probabilities for Group 4 (Figure 3.17b, Attackers) are the conditional probabilities that a specific number of attackers remain with time. For example, after 10 seconds into the simulation, the probability that one attacker has been killed is 0.458. Notice that probabilities sum to one for any column of probabilities. This is because all possibilities are represented (i.e., for any amount of elapsed time into the simulation, the probability that no attackers have been killed + the probability that one attacker has been killed +...+ the probability all six attackers have been killed must sum to 1.). The figure also gives the expected number of attackers killed with time. For example, after 20 seconds, approximately three (2.64) attackers have been killed. The model does not attempt to establish an attack or defense force quit criteria. Definition of when the engagement terminates is left to the analyst.

Graphs such as the one shown in Figures 3.18a and 3.18b may be constructed to show the expected number of targets which have been destroyed as the simulation progresses in time. This graph is intended only as an example of one method to visually display SAS results. The figures from the output listing do not necessarily correspond to values shown on the graph.

```
 CONDITIONAL PROBABILITIES FOR GROUP #1, CONSISTING OF TARGETS:
  19 [illegible]     51 [illegible]     [illegible]     [illegible]     70 [illegible]     71 [illegible]     79 W1T4     80 W2T4     81 W3T4

       1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0   20.0
  0   .57   .342   .312  [illegible]                                   .054   .058   .054   .054  0.058  0.054  0.058  0.058  0.058  0.058  0.058
  1   .32   .384   .451  [illegible]                             .25   .212   .212   .212   .212  0.212  0.212  0.212  0.212  0.212  0.212  0.212
  2  [illegible]  .153  .214  [illegible]                        .31   .317   .317   .317   .317  0.317  0.317  0.317  0.317  0.317  0.317  0.317
  3  [illegible]                                        .27      [illegible]  .253   .253   .253  0.253  0.253  0.253  0.253  0.253  0.253  0.253
  4  [illegible]                                                 [illegible]  .119   .119   .119  0.119  0.119  0.119  0.119  0.119  0.119  0.119
  5  [illegible]                                                 [illegible]  .034   .034   .034  0.034  0.034  0.034  0.034  0.034  0.034  0.034
  6  [illegible]                                                 [illegible]  [illegible]   .006  0.006  0.006  0.006  0.006  0.006  0.006  0.006
  7  [illegible]                                                 [illegible]  .001   .001   .001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
  8  [illegible]                                                 [illegible]  .000   .000   .000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  9  [illegible]                                                 [illegible]  .000   .000   .000  0.000  0.000  0.000  0.000  0.000  0.000  0.000

 EXPECTED [illegible]:

       1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0   20.0
      0.53  [illegible]                      1.75   1.95  [illegible]   2.29   2.29   2.29   2.29   2.29   2.29   2.29   2.29   2.29   2.29   2.29

 CONDITIONAL PROBABILITIES FOR GROUP #2, CONSISTING OF TARGETS:
  52 [illegible]     53 [illegible]     54 [illegible]     72 [illegible]     73 K213     74 K3T3     82 K1T4     83 K2T4     84 K3T4

       1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0   20.0
  0  [illegible]  .438  .224  [illegible]  .067  .063  [illegible]  .031  .023  0.017  0.017  0.017  0.017  0.017  0.017  0.017  0.017  0.017  0.017  0.017
  1  [illegible]  .394  .372  [illegible]  .251  .213  [illegible]         0.102  0.101  0.101  0.101  0.100  0.100  0.100  0.100  0.100  0.099  0.099
  2  [illegible]  .194  .283  [illegible]  .313  .317  [illegible]         0.241   .240   .240   .239  0.239  0.238  0.238  0.238  0.238  0.237  0.237
  3  [illegible]                           .247  .273  [illegible]         .299   0.298   .298   .296  0.296  0.298  0.298  0.298  0.298  0.298  0.298
  4  [illegible]                           .127  .157  [illegible]         .218   0.218   .217   .217  0.217  0.218  0.218  0.218  0.218  0.218  0.219
  5  [illegible]                                       [illegible]         .096   0.096   .096   .097  0.097  0.097  0.098  0.098  0.098  0.096  0.098
  6  [illegible]                                       [illegible]         .027   0.027   .027   .027  0.027  0.027  0.027  0.027  0.027  0.027  0.027
  7  [illegible]                                       [illegible]         [illegible]      .004   .004  0.004  0.004  0.005  0.005  0.005  0.005  0.005
  8  [illegible]                                       [illegible]         [illegible]             .000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  9  [illegible]                                       [illegible]         [illegible]             .000  0.000  0.000  0.000  0.000  0.000  0.000  0.000

 EXPECTED NUMBER OF TARGETS DESTROYED AFTER [illegible]:

       1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0   20.0
      0.65   1.01   1.34   1.77  [illegible]  2.31   2.57   2.75  [illegible]  3.01   3.01   3.02   3.02   3.02   3.02   3.03   3.03   3.03   3.03   3.03

 CONDITIONAL PROBABILITIES FOR GROUP #3, CONSISTING OF TARGETS:
  47 [illegible]     48 [illegible]     50 [illegible]     58 [illegible]     59 D3T2     60 D4T2     61 D5T2     62 D6T2     63 D7T2
  64 [illegible]     67 [illegible]     68 [illegible]     77 [illegible]     78 D2T3

       1.0    2.0    3.0    4.0    5.0    6.0    7.0    8.0    9.0   10.0   11.0   12.0   13.0   14.0   15.0   16.0   17.0   18.0   19.0   20.0
  0  0.005  [illegible]                                                0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  1   .03   [illegible]                                                0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  2   .171  [illegible]                                                0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  3  0.227  [illegible]                                                0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
```

FIGURE 3.17a - SAS Output Showing Expected Number of Targets Destroyed With Time

```
EXPECTED NUMBER OF TARGETS DESTROYED AFTER TIME ELAPSED:

    1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0
   3.95 5.80 6.98 7.61 8.15 8.25 8.35 8.45 8.53 8.59 8.65 8.69 8.75 8.79 8.81 8.84 8.86 8.88 8.91 8.92


CONDITIONAL PROBABILITIES FOR GROUP #4, CONSISTING OF TARGETS:
 87 K1        88 K2        89 K3        90 K4        91 K5        92 K6

      1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0  13.0  14.0  15.0  16.0  17.0  18.0  19.0  20.0
 0  1.000 1.000 0.898 0.834 0.805 0.774 0.747 0.720 0.463 0.341 0.250 0.185 0.105 0.077 0.056 0.041 0.024 0.018 0.013 0.010
 1  0.000 0.000 0.100 0.157 0.184 0.211 0.234 0.257 0.409 0.458 0.470 0.457 0.376 0.332 0.284 0.243 0.174 0.145 0.120 0.098
 2  0.000 0.000 0.003 0.007 0.010 0.014 0.018 0.023 0.115 0.179 0.246 0.312 0.394 0.421 0.435 0.436 0.402 0.382 0.357 0.327
 3  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.012 0.022 0.032 0.044 0.112 0.148 0.193 0.239 0.316 0.351 0.379 0.399
 4  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.001 0.002 0.002 0.013 0.020 0.029 0.040 0.077 0.094 0.117 0.145
 5  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.001 0.002 0.003 0.007 0.010 0.014 0.020
 6  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.001


EXPECTED NUMBER OF TARGETS DESTROYED AFTER TIME ELAPSED:

    1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0
   0.00 0.00 0.11 0.16 0.21 0.24 0.27 0.30 0.68 0.89 1.07 1.22 1.55 1.70 1.86 2.00 2.27 2.39 2.51 2.64


CONDITIONAL PROBABILITIES FOR GROUP #5, CONSISTING OF TARGETS:
 55 ET1        65 ET2        76 ET3        95 ET4

      1.0   2.0   3.0   4.0   5.0   6.0   7.0   8.0   9.0  10.0  11.0  12.0  13.0  14.0  15.0  16.0  17.0  18.0  19.0  20.0
 0  0.527 0.454 0.378 0.344 0.317 0.290 0.263 0.245 0.231 0.217 0.217 0.217 0.070 0.070 0.070 0.070 0.070 0.070 0.070 0.070
 1  0.377 0.397 0.413 0.422 0.425 0.426 0.428 0.428 0.427 0.430 0.430 0.430 0.271 0.271 0.271 0.271 0.271 0.271 0.271 0.271
 2  0.084 0.129 0.160 0.192 0.213 0.227 0.244 0.254 0.265 0.274 0.274 0.274 0.379 0.379 0.379 0.379 0.379 0.379 0.379 0.379
 3  0.012 0.019 0.027 0.038 0.047 0.052 0.060 0.065 0.069 0.072 0.072 0.072 0.229 0.229 0.229 0.229 0.229 0.229 0.229 0.229
 4  0.001 0.001 0.002 0.003 0.003 0.004 0.005 0.005 0.005 0.007 0.007 0.007 0.051 0.051 0.051 0.051 0.051 0.051 0.051 0.051


EXPECTED NUMBER OF TARGETS DESTROYED AFTER TIME ELAPSED:

    1.0  2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0
   0.59 0.72 0.82 0.93 1.01 1.05 1.12 1.16 1.17 1.22 1.22 1.22 1.92 1.92 1.92 1.92 1.92 1.92 1.92 1.92
```

FIGURE 3.17b SAS Output Showing Expected Number of Targets Destroyed With Time

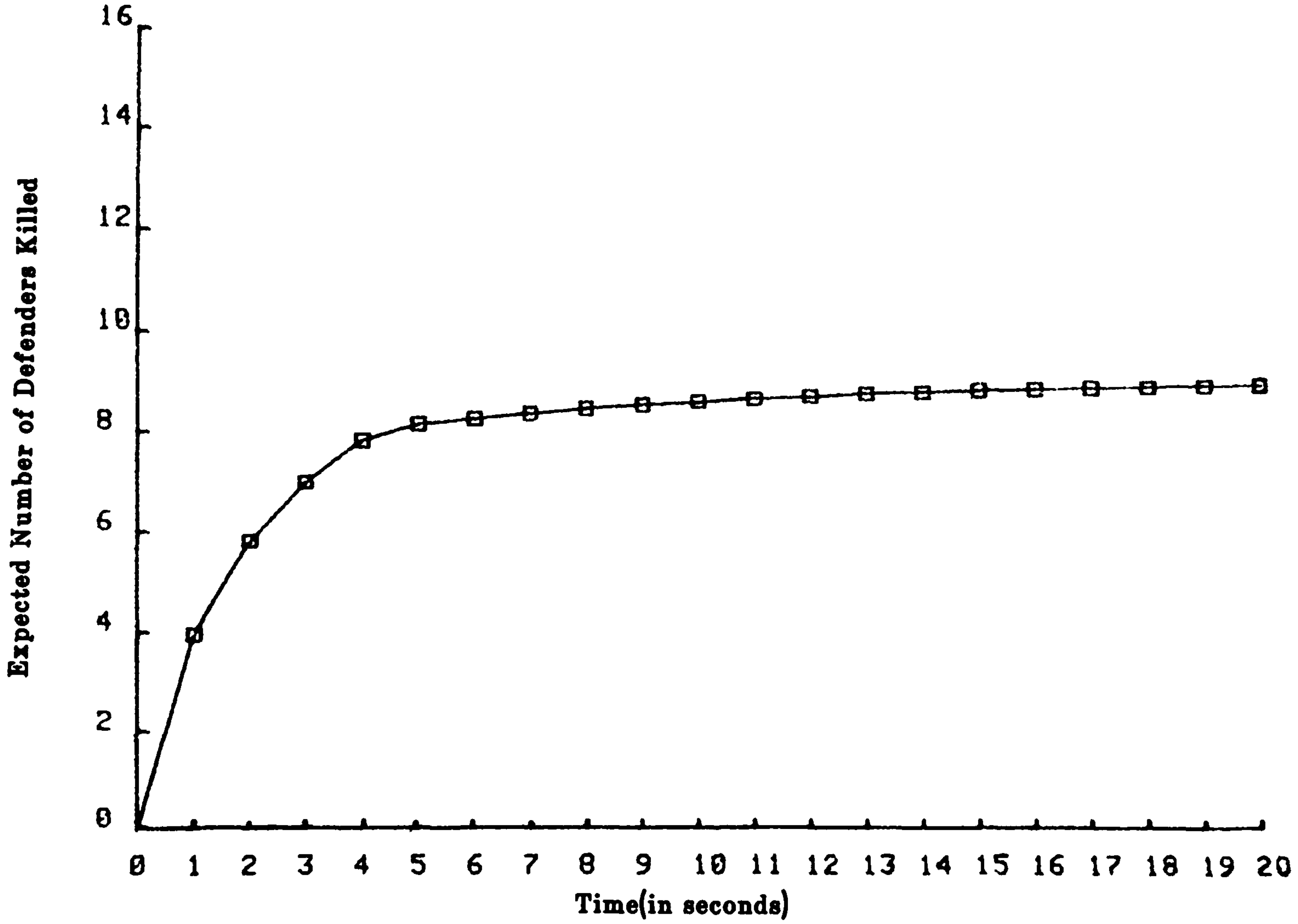


Figure 3.18a Plot of Expected Number of Targets Destroyed Versus Time From Beginning of Simulation

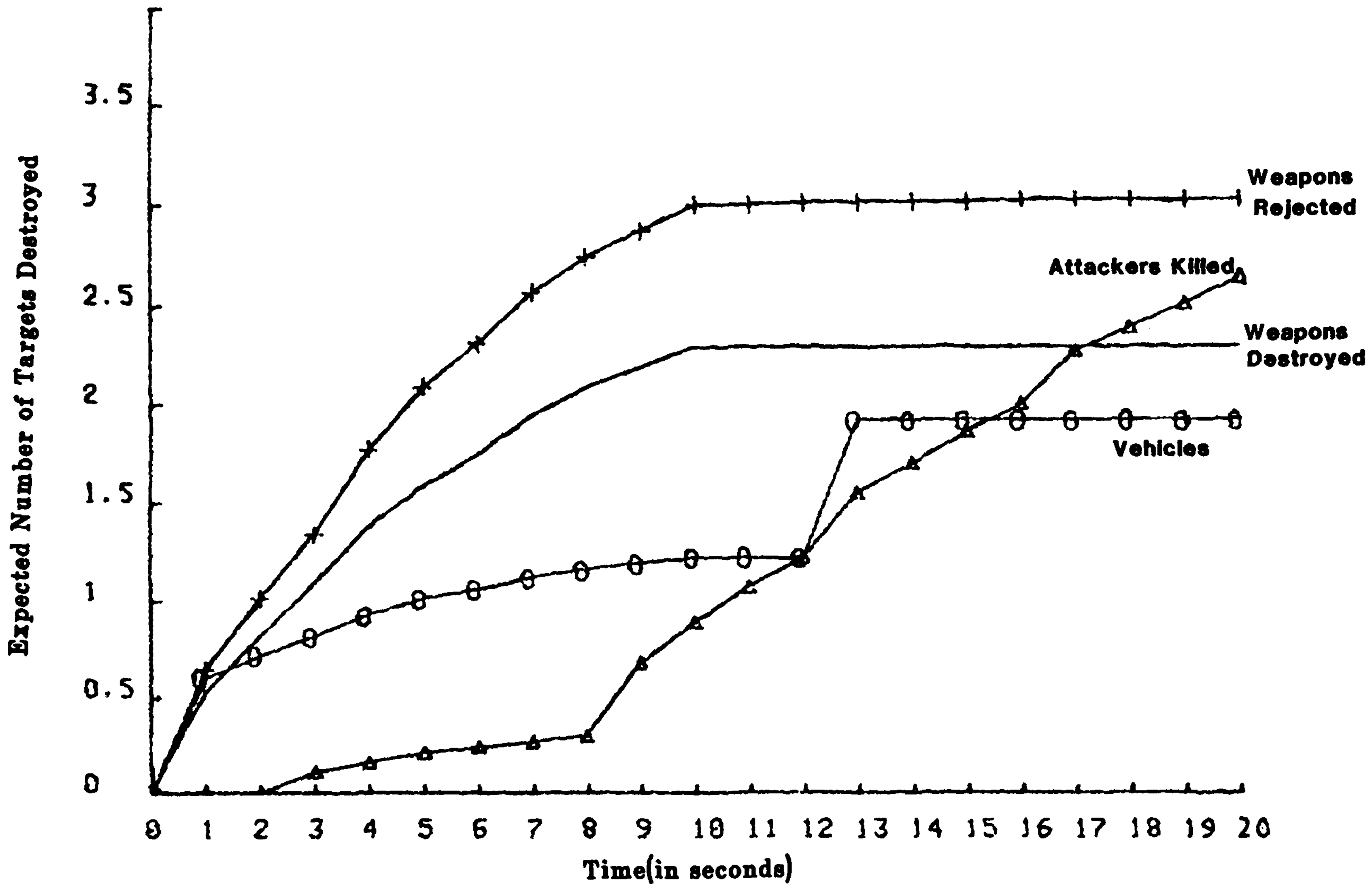


Figure 3.18b Plot of Expected Number of Targets Destroyed Versus Time From Beginning of Simulation

SECTION 4

EXAMPLE TERMINAL SESSION

```
*********************************************************************
*               A typical user terminal session is presented to illustrate    *
*       how SAS would be used to perform analysis of the example scenario     *
*       presented in Chapter * , Example Application.  This information is    *
*       intended to aid the user in understanding the SAS data entry pro-     *
*       cedure.  Comments, enclosed in asterisks, contain explanatory         *
*       remarks.                                                              *
*               Following the normal log-on procedure, the user begins the    *
*       terminal session which follows.                                       *
*********************************************************************

$RUN SAS
NAME OF INPUT DATA FILE?
INPUT.DAT
MODIFY TARGETS OR RUN? M=MODIFY, R=RUN
R
START TIME, END TIME FOR SIMULATION OUTPUT?

*********************************************************************
*               Since this is the first SAS execution of this scenario, the   *
*       data base files have not been initialized.  In order to initialize    *
*       these files prior to data entry, the user presses 'Z' while holding   *
*       the CTRL key down(denoted by CTRL Z).  After data base files have     *
*       been initialized, this question is again asked and at that point the *
*       user will enter the starting and ending simulation times.             *
*********************************************************************

CTRL Z
1-INITIALIZE PROBABILITY DATA BASE
2-INITIALIZE TARGET DATA BASE
3-INITIALIZE AIM POINT DATA BASE
4-EXAMINE PROB. DATA BASE VALUE
5-MODIFY PROB. DATA BASE VALUE
1
NAME OF NEW PROBABILITY DATA BASE FILE?
PROB.DAT
1-INITIALIZE PROBABILITY DATA BASE
2-INITIALIZE TARGET DATA BASE
3-INITIALIZE AIM POINT DATA BASE
4-EXAMINE PROB. DATA BASE VALUE
5-MODIFY PROB. DATA BASE VALUE
2
NAME OF NEW TARGET DATA BASE FILE?
TARGET.DAT
1-INITIALIZE PROBABILITY DATA BASE
2-INITIALIZE TARGET DATA BASE
3-INITIALIZE AIM POINT DATA BASE
4-EXAMINE PROB. DATA BASE VALUE
5-MODIFY PROB. DATA BASE VALUE
3
NAME OF NEW AIM POINT DATA BASE FILE?
AIM.DAT
```

```
1-INITIALIZE PROBABILITY DATA BASE
2-INITIALIZE TARGET DATA BASE
3-INITIALIZE AIM POINT DATA BASE
4-EXAMINE PROB. DATA BASE VALUE
5-MODIFY PROB. DATA BASE VALUE

****************************************************************************
*               At this point the user has initialized all of the data files *
*       required for SAS execution.  The user presses 'Z' while holding down *
*       the CTRL key to end data base initialization.                       *
****************************************************************************

CTRL Z
START TIME, END TIME FOR SIMULATION OUTPUT?
1.0 20.0
TIME INTERVAL AT WHICH RESULTS ARE DISPLAYED?
1.0
NUMBER OF HARDWARE OPTION TITLES?
3
TITLE 1?
SOT ATTACK ON GROUND CONVOY
TITLE 2?
STATE: TRANSITION
TITLE 3?
BASELINE
NAME OF FILE TO CONTAIN RESULTS?
OUTPUT.DAT
NAME OF PROBABILITY DATA BASE FILE?
PROB.DAT
TARGET DATA FILE NAME?
TARGET.DAT
ENTER TARGET INFORMATION.
TARGET NUMBER?
1
TARGET DESCRIPTION?
D1T1
TARGET HEIGHT, WIDTH?
1.2 .75
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
146. .1
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
15
NUMBER OF ROUNDS AVAILABLE?
360
RESPONSE TIME?
7.
AIM POINTS(ORDERED BY PRIORITY)?
19 22 17 18 20 21 0 0 0 0
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0
TARGET NUMBER?
```

```
2
TARGET DESCRIPTION?
D211
TARGET HEIGHT, WIDTH?
1.2 .75
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
146. .1
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
17
NUMBER OF ROUNDS AVAILABLE?
3000
RESPONSE TIME?
2.
AIM POINTS(ORDERED BY PRIORITY)?
19 22 17 16 20 21 0 0 0 0
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0

********************************************************************************
*               To avoid unnecessary repetition, all other data contained in *
*       the target data forms(Appendix A, Figure A2) for those targets in    *
*       their initial positions is entered in a similar fashion.  We will now*
*       continue with entry of data for the last target in it's initial      *
*       position.                                                            *
********************************************************************************

TARGET NUMBER?
46
TARGET DESCRIPTION?
A6
TARGET HEIGHT, WIDTH?
.125 .125
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
109. 0.
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
16
NUMBER OF ROUNDS AVAILABLE?
1000
RESPONSE TIME?
0.
AIM POINTS(ORDERED BY PRIORITY)?
14 10 13 9 15 11 7 3 0 0
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0
TARGET NUMBER?
```

```
*****************************************************************************
*              All target information on the target data forms has been    *
*       entered for targets in their initial positions.  The user now types *
*       a "Z" while depressing the CTRL key to end the target data input    *
*       section.                                                            *
*****************************************************************************

CTRL Z
AIM POINT DATA FILE NAME?
AIM.DAT
ENTER AIM POINT INFORMATION.
AIM POINT NUMBER?
1
AIM POINT DESCRIPTION?
D1T1
RANDOM OR FIXED AIM POINT? F-FIXED, R-RANDOM
F
COORDINATES OF AIM POINT X, Y?
146.375 .7
TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM POINT?
1 2 5 8 9 0 0 0 0 0 0 0 0 0 0 0
AIM POINT NUMBER?
2
AIM POINT DESCRIPTION?
D2T1
RANDOM OR FIXED AIM POINT? F-FIXED, R-RANDOM
F
COORDINATES OF AIM POINT X, Y?
146.375 .7
TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM POINT?
2 1 5 8 9 0 0 0 0 0 0 0 0 0 0 0

*****************************************************************************
*              Again to avoid undue repetition, only the last aim point will*
*       now be entered.  All other aim points which were not entered pre-   *
*       viously are entered in a similar manner.                            *
*****************************************************************************

AIM POINT NUMBER?
44
AIM POINT DESCRIPTION?
E14P2
RANDOM OR FIXED AIM POINT? F-FIXED, R-RANDOM
F
COORDINATES OF AIM POINT X, Y?
116.2 .55
TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM POINT?
40 31 32 33 34 35 36 37 38 39 0 0 0 0 0 0

*****************************************************************************
*              To end the aim point data gathering section the user types   *
*       "Z" while depressing the CTRL key.                                  *
*****************************************************************************

CTRL Z
ENTER STATUS CHANGE INFORMATION.
```

```
*******************************************************************************
*               Status change information includes both the target data for  *
*       all targets in their non-initial positions and the status change time*
*       and target numbers in the input data forms.                          *
*******************************************************************************

TARGET NUMBER?
47
TARGET DESCRIPTION?
01T1P2
TARGET HEIGHT, WIDTH?
.15 .25
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
148. -.5
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
4
NUMBER OF ROUNDS AVAILABLE?
360

*******************************************************************************
*               Notice that RESPONSE TIME is no longer required for targets  *
*       in their non-initial positions.  In place of response time, an       *
*       initial delay is requested later in the interactive terminal session.*
*       This delay is not relative to the beginning of the simulation, as is *
*       response time, rather it is relative to the time at which the target *
*       status change occurs.                                                *
*******************************************************************************

AIM POINTS(ORDERED BY PRIORITY)?
19 22 17 18 20 21 0 0 0 0
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0
STATUS CHANGE TIME, INITIAL DELAY, OLD TARGET NUMBER?
5. 0. 1
TARGET NUMBER?
48
TARGET DESCRIPTION?
02T1P2
TARGET HEIGHT, WIDTH?
.15 .25
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
155.750 -0.5
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
6
NUMBER OF ROUNDS AVAILABLE?
3000
```

```
AIM POINTS(ORDERED BY PRIORITY)?
19 22 17 18 20 21 0 0 0 0
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0
STATUS CHANGE TIME, INITIAL DELAY, OLD TARGET NUMBER?
5. 0. 2

***************************************************************************
*                 To avoid unnecessary repetition, only the data for the last  *
*        non-initial target will be given.                                     *
***************************************************************************

TARGET DESCRIPTION?
A6P2
TARGET HEIGHT, WIDTH?
.125 .125
RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM
F
TARGET AREA, LOWER: X COOR., Y COOR.?
109. 0.
CAN TARGET FIRE? Y-YES, N-NO
Y
WEAPON TYPE?
5
NUMBER OF ROUNDS AVAILABLE?
1000
AIM POINTS(ORDERED BY PRIORITY)?
42 38 41 37 29 30 31 32 33 34
TARGETS DAMAGED BY HITTING THIS TARGET?
0 0 0 0 0 0 0 0 0 0
STATUS CHANGE TIME, INITIAL DELAY, OLD TARGET NUMBER?
10. 0. 46

***************************************************************************
*                 After all status chance information has been entered, type   *
*        "Z" while holding down the CTRL key.                                  *
***************************************************************************

CTRL 7
NUMBER OF TARGETS IN GROUP?
9
TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE DISPLAYED?
49 50 51 69 70 71 79 80 81

***************************************************************************
*                 The first target group corresponds to all weapon targets.    *
*        Notice that the final target numbers are used when specifing the tar-*
*        get group, not the initial numbers.                                   *
***************************************************************************

NUMBER OF TARGETS IN GROUP?
9
TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE DISPLAYED?
52 53 54 72 73 74 82 83 84
```

```
************************************************************************
*              The second group specifies all weapon containers which if hit*
*       would result in a possible weapon rejection.                   *
************************************************************************

NUMBER OF TARGETS IN GROUP?
14
TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE DISPLAYED?
47 48 57 58 59 60 61 62 63 64 67 68 77 78

************************************************************************
*              The third group of targets correspond to the set of defend-  *
*       ders.                                                          *
************************************************************************

NUMBER OF TARGETS IN GROUP?
6
TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE DISPLAYED?
87 88 89 90 91 92

************************************************************************
*              The fourth group corresponds to all attacker targets.    *
************************************************************************

NUMBER OF TARGETS IN GROUP?
4
TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE DISPLAYED?
56 66 76 86

************************************************************************
*              The fifth group contains all vehicle engines.            *
************************************************************************


************************************************************************
*              The user has now specified all target groups he wishes to    *
*       consider for this simulation.  It so happens that in this case the  *
*       maximum number of groups(5 groups) was desired.  When the maximum   *
*       number of groups have been chosen, the model automatically proceeds *
*       to the next data item.  Since the target groups are the last data   *
*       item to enter before the simulation is run, this is all the user has *
*       to input for this example.  Should you desire fewer target groups,  *
*       this input loop may be terminated by entering 'Z' while holding the *
*       CTRL key down.                                                 *
************************************************************************


************************************************************************
*              The simulation is complete when a '$' prompt is returned to  *
*       the user's terminal.  Simulation output can be found in the output  *
*       file specified by the user(in this case the file OUTPUT.DAT was used.*
*       The user may type the file to his screen by typing TYPE OUTPUT.DAT or*
*       may list the contents of the file on the line printer by typing    *
*       PRINT OUTPUT.DAT after the '$' prompt.                          *
*       A sample of the output for this example is presented in Figure #.   *
************************************************************************
```

REFERENCES

1. G. E. P. Box and M. E. Muller, "A Note on the Generation of Random Normal Deviates", Analytical Mathematical Statistics, Volume 29, 1958, pp. 610-611.

2. G. S. Fishman, "Concepts and Methods in Discrete Event Digital Simulation", Chapter 8, pp. 211-213, John Wiley & Sons, New York, 1973.

3. C. M. Clark and M. N. Cravens, "Path Analysis (PANL) Usèr's Guide", Sandia Laboratories, SAND80-1888.

4. R. McGowan and D. Packard, "Survivability and Security Assessment of Movement-of-Weapons Issue, Volume I-Analysis, JAYCOR, unpublished.

APPENDIX A

STANDARDIZED INPUT DATA FORMS

Input information required for SAS execution is classified into three areas: target data, aim point data, and other input data. Other input data consists of all data which is not related to target or aim point data directly. The target data, aim point data and input data files will be used to store all required input for a SAS simulation. To facilitate obtaining and entering the large amount of data required for a typical SAS execution, standard data forms have been specifically designed to obtain the required data for each of the three information categories. Examples of blank data forms to gather necessary target data, aim point data and other input data are presented in Figures A.1 (a through e). The input data forms are useful in organizing input data and assuring the analyst that all necessary data has been obtained prior to execution of the SAS simulation. After data forms have been filled out and the SAS model is executed, the data on the forms is entered interactively in the same order which it is filled in on the form.

The information which is required for each data form is contained in completed data forms for this particular example, which are presented separately in Figure A.2 (a through q).

INPUT DATA FORM, page 1

Name of input data file (10 chars. max.)? ______________________________

Start, end time for simulation output? ______________________________

Time interval at which results are displayed? ______________________________

Number of hardware option titles (1-5)? ______________________________

Hardware option title 1? ______________________________

Hardware option title 2 (if no more titles, leave rest of option titles blank)?

____

Hardware option title 3 (if no more titles, leave rest of option titles blank)?

____

Hardware option title 4 (if no more titles, leave rest of option titles blank)?

____

Hardware option title 5 (if no more titles, leave rest of option titles blank)?

____

Name of file to contain results (10 chars. max.)? ______________________________

Name of probability data base file (10 chars. max.)? ______________________________

Target data file name (10 chars. max.)? ______________________________

(File out Target Data Form next)

Figure A.1a Data Forms Used to Acquire SAS Input Data (Input Data Form, page 1)

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10

Notes:

[1] - if random, X and Y are lower left corner coordinates of random target area

[2] - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, *otherwise continue* entering target data information on new target data form.

Figure A.1b Data Forms Used to Acquire SAS Input Data (Target Data Form)

Aim Point Number	Aim Point Description	Random or Fixed	X Coor.	Y Coor.^{1}	Height	Width^2	Targets which may be hit by firing at this aim point									
							1	2	3	4	5	6	7	8	9	10

Notes:
1 - if random, X and Y are coordinates of lower left corner of random firing area
2 - height and width specify the height and width of random aim point area

After all aim points have been entered, fill out Input Data Form - Page 2, otherwise
continue entering aim point data information on new aim point data form.

Figure A.1c Data Forms Used to Acquire SAS Input Data (Aim Point Data Form)

Old Target Number	New Target Number	Status Change Time	Delay Time

If all status changes have been entered, fill out Input Data Form - Page 3, otherwise continue entering status changes on new Input Data Form - Page 2.

Figure A.1d Data Forms Used to Acquire SAS Input Data (Input Data Form, page 2)

INPUT DATA FORM, page 3

Number of targets in Group 1? ______________________________

Target numbers in Group 1? ______________________________

Number of targets in Group 2? ______________________________

Target numbers in Group 2? ______________________________

Number of targets in Group 3? ______________________________

Target numbers in Group 3? ______________________________

Number of targets in Group 4? ______________________________

Target numbers in Group 4? ______________________________

Number of targets in Group 5? ______________________________

Target numbers in Group 5? ______________________________

Number of targets in Group 6? ______________________________

Target numbers in Group 6? ______________________________

Number of targets in Group 7? ______________________________

Target numbers in Group 7? ______________________________

Number of targets in Group 8? ______________________________

Target numbers in Group 8? ______________________________

Number of targets in Group 9? ______________________________

Target numbers in Group 9? ______________________________

Number of targets in Group 10? ______________________________

Target numbers in Group 10? ______________________________

When all target groups have been entered, all data required for the simulation is complete.

Figure A.1e Data Forms Used to Acquire SAS Input Data (Input Data Form, page 3)

INPUT DATA FORM, page 1

Name of input data file (10 chars. max.)? INPUT.DAT

Start, end time for simulation output? 1.0 20.0

Time interval at which results are displayed? 1.0

Number of hardware option titles (1-5)? 2

Hardware option title 1? SOT ATTACK ON GROUND CONVOY

Hardware option title 2 (if no more titles, leave rest of option titles blank)?

STATE: TRANSITION

Hardware option title 3 (if no more titles, leave rest of option titles blank)?

Hardware option title 4 (if no more titles, leave rest of option titles blank)?

Hardware option title 5 (if no more titles, leave rest of option titles blank)?

Name of file to contain results (10 chars. max.)? OUTPUT.DAT

Name of probability data base file (10 chars. max.)? PROB.DAT

Target data file name (10 chars. max.)? TARGET.DAT

(File out Target Data Form next)

Figure A.2a Completed Input Data Form, Page 1

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
1	D1T1	1.2	.75	F	146.	0.1			Y	15	360	7.	19	22	17	18	20	21														
2	D2T1	1.2	.75	F	146.	0.1			Y	17	3000	2.	19	22	17	18	20	21														
3	W1T1	.15	.7	F	141.4	.175			N														1	2	4	5	6	7	8	9		
4	W2T1	.15	.7	F	142.8	.175			N														1	2	3	5	6	7	8	9		
5	W3T1	.15	.7	F	144.1	.175			N														1	2	3	4	6	7	8	9		
6	K1T1	.5	1.5	F	140.8	0.			N																							
7	K2T1	.5	1.5	F	142.4	0.			N																							
8	K3T1	.5	1.5	F	143.9	0.			N																							
9	GT1	.4	1.4	F	144.1	-0.4			N																							
10	ET1	1.1	1.6	F	147.1	0.			N																							
11	D1T2	1.2	.75	F	117.2	.1			Y	15	360	8.67	19	22	18	17	20	21														
12	D2T2	1.2	.75	F	117.2	.1			Y	17	3000		19	22	18	17	20	21														
13	D3T2	1.2	.75	F	112.	.5			Y	15	360	8.67	19	22	18	17	20	21														

Notes:
[1] - if random, X and Y are lower left corner coordinates of random target area
[2] - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2b Completed Target Data Form, Targets 1-13

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
14	D4T2	1.2	.75	F	112.8	.5			Y	17	3000	8.67	19	22	18	17	20	21														
15	D5T2	1.2	.75	F	113.6	.5			Y	20	100	8.67	19	22	18	17	20	21														
16	D6T2	1.2	.75	F	114.4	.5			Y	17	3000	8.67	19	22	18	17	20	21														
17	D7T2	1.2	.75	F	115.2	.5			Y	17	3000	8.67	19	22	18	17	20	21														
18	D8T2	1.2	.75	F	116.	.5			Y	15	360	8.67	19	22	18	17	20	21														
19	GT2	.4	1.4	F	115.4	-0.4			N														11	12	13	14	15	16	17	18	20	
20	ET2	1.1	1.6	F	118.4	0.			N																							
21	D1T3	1.2	.75	F	88.75	.1			Y	15	360	10.33	22	19	20	18	21	17														
22	D2T3	1.2	.75	F	88.75	.1			Y	17	3000	2.	22	19	20	18	21	17														
23	W1T3	.15	.7	F	84.17	.175			N														21	22	24	25	26	27	28	29	30	
24	W2T3	.15	.7	F	85.55	.175			N														21	22	23	25	26	27	28	29	30	
25	W3T3	.15	.7	F	86.92	.175			N														21	22	23	24	26	27	28	29	30	
26	K1T3	.5	1.5	F	83.57	0.			N																							

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2c Completed Target Data Form, Targets 14-26

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
27	K2T3	.5	1.5	F	85.15	0.			N																							
28	K3T3	.5	1.5	F	86.72	0.			N																							
29	GT3	.4	1.4	F	86.9	-0.4			N														21	22	23	24	25	26	27	28	30	
30	ET3	1.1	1.6	F	89.9	0.			N																							
31	D1T4	1.2	.75	F	60.	.1			Y	15	360	12.	22	19	21	20	18	17														
32	D2T4	1.2	.75	F	60.	.1			Y	17	3000	2.	22	19	21	20	18	17														
33	W1T4	.15	.7	F	55.42	.175			N														31	32	34	35	36	37	38	39	40	
34	W2T4	.15	.7	F	56.8	.175			N														31	32	33	35	36	37	38	39	40	
35	W3T4	.15	.7	F	58.17	.175			N														31	32	33	34	36	37	38	39	40	
36	K1T4	.5	1.5	F	54.82	0.			N																							
37	K2T4	.5	1.5	F	56.4	0.			N																							
38	K3T4	.5	1.5	F	56.4	0.			N																							
39	GT4	.4	1.4	F	58.15	-0.4			N														31	32	33	34	35	36	37	38	40	

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2d Completed Target Data Form, Targets 27-39

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
40	ET4	1.1	1.6	F	61.15	0.			N																							
41	A1	.125	.125	F	155.2	0.			Y	21	6	0.	4	8	12	16	3	7	11	15												
42	A2	.125	.125	F	142.2	0.			Y	21	6	0.	8	4	12	16	7	3	11	15												
43	A3	.125	.125	F	135.	0.			Y	16	1000	0.	2	6	1	5	3	7	11	15												
44	A4	.125	.125	F	129.4	0.			Y	21	6	0.	12	16	8	4	11	15	7	3												
45	A5	.125	.125	F	116.2	0.			Y	21	6	0.	16	12	8	4	15	11	7	3												
46	A6	.125	.125	F	109.	0.			Y	16	1000	0.	14	10	13	9	15	11	7	3												
47	D1T1P2	.15	.25	F	148.	-0.8			Y	4	360	7.	19	22	17	18	20	21														
48	D2T1P2	.15	.25	F	155.7	-0.8			Y	6	3000	2.	19	22	17	18	20	21														
49	W1T1P2	.15	.7	F	148.6	.175			N														47	48	50	51	52	53	54	55	56	
50	W2T1P2	.15	.7	F	150.	.175			N														47	48	49	51	52	53	54	55	56	
51	W3T1P2	.15	.7	F	151.4	.175			N														47	48	49	50	52	53	54	55	56	
52	K1T1P2	.5	1.5	F	148.	0.			N																							

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2e Completed Target Data Form, Targets 40-52

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
53	K2T1P2	.5	1.5	F	149.6	0.			N																							
54	K3T1P2	.5	1.5	F	151.2	0.			N																							
55	GT1P2	.4	1.4	F	151.4	-0.4			N														47	48	49	50	51	52	53	54	56	
56	ET1P2	1.1	1.6	F	154.4	0.			N																							
57	D1T2P2	.15	.25	F	142.7	-0.8			Y	4	360	8.67	19	22	18	17	20	21														
58	D2T2P2	1.2	.75	F	140.2	.1			Y	6	3000	8.67	19	22	18	17	20	21														
59	D3T2P2	.15	.25	F	135.	-0.8			Y	4	360	8.67	19	22	18	17	20	21														
60	D4T2P2	.15	.25	F	136.2	-0.8			Y	6	3000	8.67	19	22	18	17	20	21														
61	D5T2P2	.15	.25	F	137.5	-0.8			Y	9	100	8.67	19	22	18	17	20	21														
62	D6T2P2	.15	.25	F	138.8	-0.8			Y	6	3000	8.67	19	22	18	17	20	21														
63	D7T2P2	.15	.25	F	140.1	-0.8			Y	6	3000	8.67	19	22	18	17	20	21														
64	D8T2P2	.15	.25	F	141.4	-0.8			Y	4	360	8.67	19	22	18	17	20	21														
65	GT2P2	0.4	1.4	F	138.4	-0.4			N														57	58	59	60	61	62	63	64	66	

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - height and width for the random target area are not used if target is fixed

After all target information .as been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2f Completed Target Data Form, Targets 53-65

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
66	ET2P2	1.1	1.6	F	141.4	0.			N																							
67	D1T3P2	.15	.25	F	129.7	-0.8			Y	4	360	10.33	22	19	20	18	21	17														
68	D2T3P2	1.2	.75	F	127.2	.1			Y	6	3000	2.	22	19	20	18	21	17														
69	W1T3P2	.15	.7	F	122.6	.175			N														67	68	70	71	72	73	74	75	76	
70	W2T3P2	.15	.7	F	124.	.175			N														67	68	69	71	72	73	74	75	76	
71	W3T3P2	.15	.7	F	125.4	.175			N														67	68	69	70	72	73	74	75	76	
72	K1T3P2	.5	1.5	F	122.0	0.			N																							
73	K2T3P2	.5	1.5	F	123.6	0.			N																							
74	K3T3P2	.5	1.5	F	125.2	0.			N																							
75	GT3P2	.4	1.4	F	125.4	-0.4			N														67	68	69	70	71	72	73	74	76	
76	ET3P2	1.1	1.6	F	128.4	0.			N																							
77	D1T4P2	.15	.25	F	116.7	-0.8			Y	4	360	12.	22	19	21	20	18	17														
78	D2T4P2	1.2	.75	F	114.2	.1			Y	6	3000	2.	22	19	21	20	18	17														

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - *height and width for the random target area are not used if target is fixed*

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2g Completed Target Data Form, Targets 66-78

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
79	W1T4P2	.15	.7	F	109.6	.175			N														77	78	80	81	82	83	84	85	86	
80	W2T4P2	.15	.7	F	111.	.175			N														77	78	79	81	82	83	84	85	86	
81	W3T4P2	.15	.7	F	112.4	.175			N														77	78	79	80	82	83	84	85	86	
82	K1T4P2	.5	1.5	F	109.0	0.			N																							
83	K2T4P2	.5	1.5	F	110.6	0.			N																							
84	K3T4P2	.5	1.5	F	112.2	0.			N																							
85	GT4P2	.4	1.4	F	112.4	-0.4			N														77	78	79	80	81	82	83	84	86	
86	ET4P2	1.1	1.6	F	115.4	0.			N																							
87	A1P2	.125	.125	F	155.2	0.			Y	10	6	0.	26	36	40	44	25	35	39	43												
88	A2P2	.125	.125	F	142.2	0.			Y	10	6	0.	36	26	40	44	35	25	39	43												
89	A3P2	.125	.125	F	135.	0.			Y	5	1000	0.	24	28	23	27	29	31	32	33	34	30										
90	A4P2	.125	.125	F	129.4	0.			Y	10	6	0.	40	44	36	26	39	43	35	25												
91	A5P2	.125	.125	F	116.2	0.			Y	10	6	0.	44	40	36	26	43	39	35	25												

Notes:
1 - if random, X and Y are lower left corner coordinates of random target area
2 - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2h Completed Target Data Form, Targets 79-91

Target Number	Target Description	Target		Random or Fixed	Lower Left Coor.[1]		Random Area		Can target fire? (Y or N)	Weapon Type	Number of Rounds	Response Time	Aim Points, Ordered by Priority										Collaterally Damaged Targets									
		Height	Width		X	Y	Height	Width[2]					1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
92	A6P2	.125	.125	F	109.	0.			Y	5	1000	0.	42	38	41	37	29	30	31	32	33	34										

Notes:

[1] - if random, X and Y are lower left corner coordinates of random target area

[2] - height and width for the random target area are not used if target is fixed

After all target information has been entered, fill out aimpoint data form, otherwise continue entering target data information on new target data form.

Figure A.2i Completed Target Data Form, Target 92

Aim Point Number	Aim Point Description	Random or Fixed	X Coor.	Y Coor.^{1}	Height	Width^2	Targets which may be hit by firing at this aim point									
							1	2	3	4	5	6	7	8	9	10
1	D1T1	F	146.375	0.7			1	2	5	8	9					
2	D2T1	F	146.375	0.7			2	1	5	8	9					
3	CT1	R	140.75	0.	3.	4.8	9	1	2	3	4	5	6	7	8	
4	ET1	F	147.95	.55			10	1	2	3	4	5	6	7	8	9
5	D1T2	F	117.625	0.7			11	12	17	18	19					
6	D2T2	F	117.625	0.7			12	11	17	18	19					
7	CT2	R	112.	0.	3.	4.8	16	11	12	13	14	15	17	18	19	
8	ET2	F	119.2	.55			20	11	12	13	14	15	16	17	18	19
9	D1T3	F	89.125	0.7			21	22	25	28	29					
10	D2T3	F	89.125	0.7			22	21	25	28	29					
11	CT3	R	83.5	0.	3.	4.8	29	21	22	23	24	25	26	27	28	
12	ET3	F	90.7	.55			30	21	22	23	24	25	26	27	28	29
13	D1T4	F	60.375	0.7			31	32	35	38	39					

Notes:
1 - if random, X and Y are coordinates of lower left corner of random firing area
2 - height and width specify the height and width of random aim point area

After all aim points have been entered, fill out Input Data Form - Page 2, otherwise continue entering aim point data information on new aim point data form.

Figure A.2j Completed Aim Point Data Form, Aim Points 1-13

Aim Point Number	Aim Point Description	Random or Fixed	X Coor.	Y Coor.[1]	Height	Width[2]	Targets which may be hit by firing at this aim point									
							1	2	3	4	5	6	7	8	9	10
14	D2T4	F	60.375	0.7			32	31	35	38	39					
15	CT4	R	54.75	0.	3.	4.8	39	31	32	33	34	35	36	37	38	
16	ET4	F	61.95	.55			40	31	32	33	34	35	36	37	38	39
17	A1	R	153.763	-0.438	1.	3.	41	42	43	44	45	46				
18	A2	R	140.763	-0.438	1.	3.	42	41	43	44	45	46				
19	A3	R	133.563	-0.438	1.	3.	43	41	42	44	45	46				
20	A4	R	127.963	-0.438	1.	3.	44	41	42	43	45	46				
21	A5	R	114.763	-0.438	1.	3.	45	41	42	43	44	46				
22	A6	R	107.563	-0.438	1.	3.	46	41	42	43	44	45				
23	D1T1P2	F	148.125	-0.725			1	3	6	7						
24	D2T1P2	F	155.875	-0.725			2									
25	CT1P2	R	148.	0.	3.	4.8	9	1	3	4	5	6	7	8		
26	ET1P2	F	155.2	.55			10	1	2	3	4	5	6	7	8	9

Notes:
1 - if random, X and Y are coordinates of lower left corner of random firing area
2 - height and width specify the height and width of random aim point area

After all aim points have been entered, fill out Input Data Form - Page 2, otherwise continue entering aim point data information on new aim point data form.

Figure A.2k Completed Aim Point Data Form, Aim Points 14-26

Aim Point Number	Aim Point Description	Random or Fixed	X Coor.	Y Coor.[1]	Height	Width[2]	Targets which may be hit by firing at this aim point									
							1	2	3	4	5	6	7	8	9	10
27	D1T2P2	F	142.875	-0.725			11	18								
28	D2T2P2	F	140.375	0.7			12	16	17	18	19					
29	D3T2P2	F	135.125	-0.725			13	14								
30	D4T2P2	F	136.415	-0.725			14	13	15	16						
31	D5T2P2	F	137.705	-0,725			15	14	16	19						
32	D6T2P2	F	138.755	-0.725			16	15	17	19						
33	D7T2P2	F	140.295	-0.725			17	16	18	19						
34	D8T2P2	F	141.585	-0.725			18	17	19							
35	CT2P2	R	135.	0.	3.	4.8	15	12	13	14	16	17	18	19		
36	ET2P2	F	142.2	.55			20	11	12	13	14	15	16	17	18	19
37	D1T3P2	F	129.875	-0.725			21									
38	D2T3P2	F	127.625	0.7			22	25	28	29						
39	CT3P2	F	122.	0.	3.	4.8	29	22	23	24	25	26	27	28		

Notes:
1 - if random, X and Y are coordinates of lower left corner of random firing area
2 - height and width specify the height and width of random aim point area

After all aim points have been entered, fill out Input Data Form - Page 2, otherwise continue entering aim point data information on new aim point data form.

Figure A.21 Completed Aim Point Data Form, Aim Points 27-39

AD-A116 922 JAYCOR ALBUQUERQUE NM F/G 15/7
USER'S GUIDE FOR THE SAS (STAND-OFF ATTACK SIMULATION) COMPUTER--ETC(U)
JAN 82 C M CLARK, J T HUMPHREY, L W KENNEDY DNA001-79-C-0463
UNCLASSIFIED DNA-5845T NL

2 OF 2
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8-82
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Aim Point Number	Aim Point Description	Random or Fixed	X Coor.	Y Coor.[1]	Height	Width[2]	Targets which may be hit by firing at this aim point									
							1	2	3	4	5	6	7	8	9	10
40	ET3P2	F	129.2	.55			30	21	22	23	24	25	26	27	28	29
41	D1T4P2	F	116.875	-0.725			31									
42	D2T4P2	F	114.625	0.7			32	35	38	39						
43	CT4P2	R	109.	0.	3.	4.8	39	32	33	34	35	36	37	38		
44	ET4P2	F	116.2	.55			40	31	32	33	34	35	36	37	38	39

Notes:
1 - if random, X and Y are coordinates of lower left corner of random firing area
2 - height and width specify the height and width of random aim point area

After all aim points have been entered, fill out Input Data Form - Page 2, otherwise continue entering aim point data information on new aim point data form.

Figure A.2m Completed Aim Point Data Form, Aim Points 40-44

Old Target Number	New Target Number	Status Change Time	Delay Time
1	47	5.0	0.
2	48	5.0	0.
3	49	5.0	0.
4	50	5.0	0.
5	51	5.0	0.
6	52	5.0	0.
7	53	5.0	0.
8	54	5.0	0.
9	55	5.0	0.
10	56	5.0	0.
11	57	6.67	0.
12	58	6.67	0.
13	59	6.67	0.
14	60	6.67	0.
15	61	6.67	0.
16	62	6.67	0.
17	63	6.67	0.
18	64	6.67	0.
19	65	6.67	0.

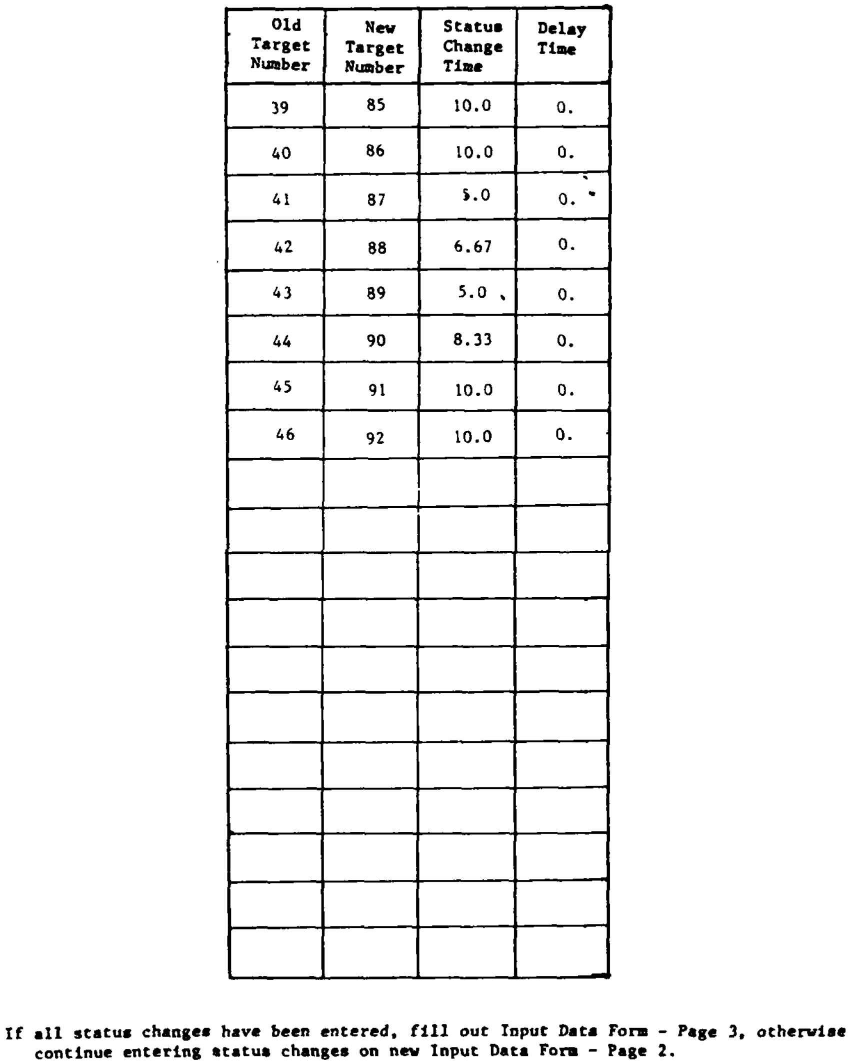
If all status changes have been entered, fill out Input Data Form - Page 3, otherwise continue entering status changes on new Input Data Form - Page 2.

Figure A.2n Completed Input Data Form, Page 2, Targets 1-19

Old Target Number	New Target Number	Status Change Time	Delay Time
20	66	6.67	0.
21	67	8.33	0.
22	68	8.33	0.
23	69	8.33	0.
24	70	8.33	0.
25	71	8.33	0.
26	72	8.33	0.
27	73	8.33	0.
28	74	8.33	0.
29	75	8.33	0.
30	76	8.33	0.
31	77	10.0	0.
32	78	10.0	0.
33	79	10.0	0.
34	80	10.0	0.
35	81	10.0	0.
36	82	10.0	0.
37	83	10.0	0.
38	84	10.0	0.

If all status changes have been entered, fill out Input Data Form - Page 3, otherwise continue entering status changes on new Input Data Form - Page 2.

Figure A.2o Completed Input Data Form, Page 2, Targets 20-38



Old Target Number	New Target Number	Status Change Time	Delay Time
39	85	10.0	0.
40	86	10.0	0.
41	87	5.0	0.
42	88	6.67	0.
43	89	5.0	0.
44	90	8.33	0.
45	91	10.0	0.
46	92	10.0	0.

If all status changes have been entered, fill out Input Data Form - Page 3, otherwise continue entering status changes on new Input Data Form - Page 2.

Figure A.2p Completed Input Data Form, Page 2. Targets 39-46

INPUT DATA FORM, page 3

Number of targets in Group 1? 9

Target numbers in Group 1? 49 50 51 69 70 71 79 80 81

Number of targets in Group 2? 9

Target numbers in Group 2? 52 53 54 72 73 74 82 83 84

Number of targets in Group 3? 14

Target numbers in Group 3? 47 48 57 58 59 60 61 62 63 64 67 68 77 78

Number of targets in Group 4? 6

Target numbers in Group 4? 87 88 89 90 91 92

Number of targets in Group 5? 4

Target numbers in Group 5? 56 66 76 86

Number of targets in Group 6?

Target numbers in Group 6?

Number of targets in Group 7?

Target numbers in Group 7?

Number of targets in Group 8?

Target numbers in Group 8?

Number of targets in Group 9?

Target numbers in Group 9?

Number of targets in Group 10?

Target numbers in Group 10?

Figure A.2q Completed Input Data Form, Page 3

APPENDIX B

GENERAL MODEL INFORMATION

B.1 SAS MODEL FLOW STRUCTURE

The SAS computer model consists of a main executive routine and five subroutines. The major function of the executive routine is to modify the probability of target existence array and schedule the next event to occur as the simulation progresses. The main routine directly communicates with three of the five subroutines. Subroutine GINPUT is the first routine called by the main program. GINPUT is called to obtain all necessary input required to perform the simulation. This routine also insures that probabilities of hit have been computed for all target/aim point/firer combinations when targets are in their initial positions.

As the simulation proceeds, requests to modify the status of certain targets will occur. Subroutine STATCHG is called to insure the parameter data describing the new target status has been stored and probabilities of hit are computed for the target whose status has been modified.

After the simulation has finished, subroutine CONDPRO is executed to evaluate the expected number of targets destroyed and conditional probability that a fixed number of targets remain with time.

Subroutine GETPTH is called from both subroutines GINPUT and TAREXEC. Subroutine GETPTH determines the probability of hit for a specific target, firer, and aim point combination.

Subroutine TAREXEC is called from subroutine STATCHG. Subroutine TAREXEC is used to handle data base storage and retrieval of information required to perform the target status change. Once the proper information describing the new target status has been obtained and stored, subroutine GETPTH is called to evaluate the probability of hit for the status change target.

The general flow structure of routine calls within the SAS model is summarized in Figure B.1.

B.2 STORAGE REQUIREMENTS

SAS creates a direct access data base file used to store probability of hit for each combination of target, aim point, and firer. Disk storage requirements used to store the SAS program source code, object code, and data base file are approximately 20K blocks, where each block contains 512 bytes or characters. The amount of storage required depends on the complexity of the simulation. The estimate of 20K blocks is based on a simulation with a comparable level of detail as the example presented in Section 3.

B.3 SYSTEM CONFIGURATION

The SAS model was developed on a VAX 11/780 computer system utilizing the following peripherals:

Memory: 768K bytes Extended Core Storage (ECC)
MOS memory (with floating point accelerator)

Disk Drives: RM03-67 megabyte hard disk drive

Printer: LP05-600 lines per minute

Terminal: VT-100

The operating system used while running the SAS simulation model was the VAX/VMS virtual memory operating system.

B.4 SOURCE LANGUAGE

The SAS computer model is written entirely in extended VAX FORTRAN IV. Although an extended type FORTRAN was used, an attempt was made to minimize the use of instructions which would not be available in ANSI standard FORTRAN, thus allowing the code to be transferred to another type computer more quickly.

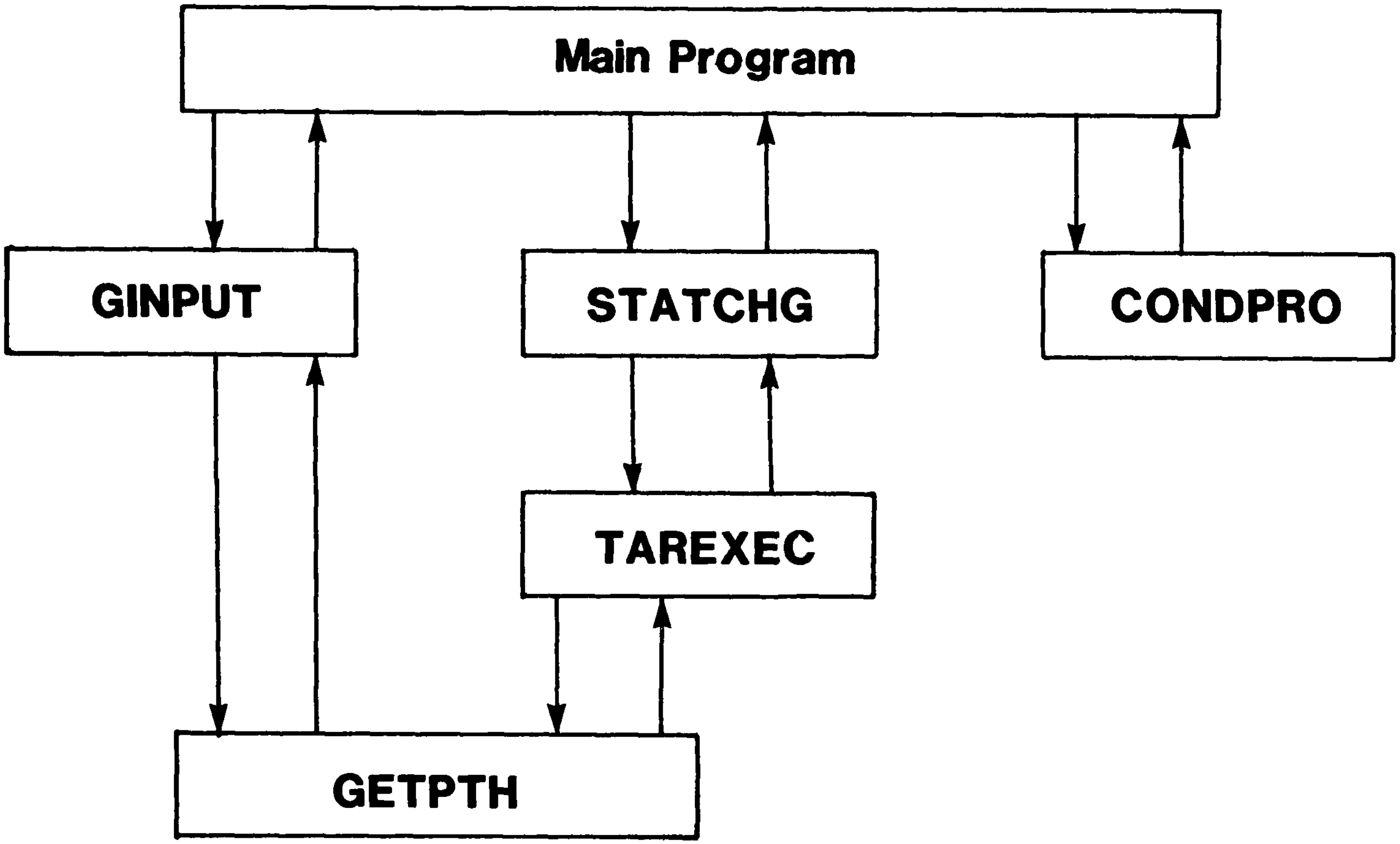


Figure B.1 SAS Routine Flow Structure

APPENDIX C

DOCUMENTED SAS CODE LISTING

C.1 INCLUDE FILE

The include file used by SAS contains a set of parameter statements used to define array dimensions and selected variable values used by the SAS model. Should the size of an array need to be altered by the user for a particular application, the user may appropriately adjust the array dimension parameters defined in the include file without modifying the SAS model. The model may then be recompiled and executed with the new array dimensions used. Whenever the statement INCLUDE 'W.INC' appears in the documented SAS computer listing, all statements contained in the include file are inserted.

```
C        W.INC -- Constants used in SAS.
    PARAMETER MAIMPRY = 10       ! Maximum number of aim points per
C                                ! target, ordered by priority
    PARAMETER MAIMPTS = 60       ! Maximum number of aim points
    PARAMETER MGROUPS = 10       ! Maximum number of groups in TGROUPS
    PARAMETER WSEED1 = 23        ! Initial seed value for RANDU
    PARAMETER WSEED2 = 41        ! Initial seed value for RANDU
    PARAMETER WSEPOIS = 75       ! Minimum separation distance
    PARAMETER WSHOTS = 100       ! Number of shots fired to find a
C                                ! probability from, using Monte Carlo techniques
    PARAMETER WSTATC = 99        ! Maximum number of status changing targets
    PARAMETER WTARGS = 140       ! Maximum number of targets
    PARAMETER WICOLAT = 15       ! Maximum number of collateral targets
C                                ! destroyed when a target is destroyed
    PARAMETER MTMITGA = 16       ! Maximum number of targets than can be
C                                ! hit, given an aim point
    PARAMETER MTITLEL = 30       ! Maximum length (in 2-byte words) of hardware
C                                ! option title
    PARAMETER MTITLES = 5        ! Maximum number of hardware option titles
    PARAMETER MTMINTS = 20       ! Maximum number of time intervals
    PARAMETER MWTYPES = 22       ! Maximum number of weapon types
C        end of W.INC.
```

C.2 DOCUMENTED SAS CODE LISTING

A documented code listing of the SAS computer model is provided in this section. The listing is intended for the reader who desires specific details on the operation of the model.

```
PROGRAM SAS
INCLUDE "M.INC"
COMMON /L1/ WCEP(MWTYPES)                !Aimming error array.
COMMON /L2/ WRATE(MWTYPES)               !weapon firing rate array.
COMMON /L4/ PTEXIST(MTARGS)              !Probability that a particular
                                         !  target exists with time.
COMMON /L5/ EVENTTM(MTARGS)              !EVENTTM(I) - Next status
                                         !  change event time for tar-
                                         !  get I.
COMMON /L6/ NUMTAR(MTARGS)               !Array of target numbers.
COMMON /L7/ ITARDES(MTARGS, 5)           !Array of 10 character target
                                         !  descriptions.
COMMON /L8/ TARCHAR(MTARGS, 6)           !Array containing target data.
COMMON /L9/ NWTYPE(MTARGS)               !Array containing firer's
                                         !  weapon type.
COMMON /L10/ NROUNDS(MTARGS)             !Number of rounds available to
                                         !  each firer.
COMMON /L11/ NAIMPRY(MTARGS, MAIMPRY)    !Array listing aim points by
                                         !  priority for each firer.
                                         !  NAIMPRY(I,1 thru MAIMPRY)
                                         !  contains all aim points for
                                         !  firer I, with NAIMPRY(I,1)
                                         !  being most important,
                                         !  NAIMPRY(I,2) being second,
                                         !  and so on.
COMMON /L12/ MTCOLAT(MTARGS, MTCOLAT)    !Array specifing targets which
                                         !  may be collaterily damaged.
                                         !  MTCOLAT(I,1 thru MTCOLAT)
                                         !  contains all targets which
                                         !  may be collaterily damaged
                                         !  by hitting target NUMTAR(I).
COMMON /L13/ NUMAIMP(MAIMPTS)            !Array of aim point numbers.
COMMON /L14/ IAIMDES(MAIMPTS, 5)         !Array of 10 character aim point
                                         !  descriptions.
COMMON /L15/ AIMCHAR(MAIMPTS, 4)         !  Array of aim point data.
COMMON /L16/ NTHITGA(MAIMPTS, MTHITGA)   !Array specifing a list of tar-
                                         !  gets which could be hit by
                                         !  firing at aim point
                                         !  NUMAIMP(I).
COMMON /L17/ RESULTS(MTARGS, MTMINTS)    !Array used to store simulation
                                         !  results. RESULTS(I,J) would
                                         !  contain the probability that
                                         !  target I would still exist
                                         !  after J time intervals have
                                         !  elapsed.
COMMON /L18/ PTARHIT(MTARGS, MAIMPRY, MTHITGA) !Array used to store
                                         !  probabilities of hit.
                                         !  PTARHIT(I,J,K) contains the
                                         !  the probability that firer
                                         !  NUMTAR(I) fires at aim point
                                         !  NUMAIMP(J) and hits target
                                         !  NUMTAR(K).
COMMON /L19/ NAMEOPF(5)                  !Name of output file where
                                         !  results are to be written.
                                         !  Maximum of 10 characters.
                                         !  ulation.
      REAL PTEXSV(MTARGS), RTIME(MTMINTS)   !PTEXSV is used to temporarily
                                         !  save the PIEXIST array while
                                         !  computing collateral damage
                                         !  effects.
                                         !  RTIME is used to print out
                                         !  time headings in results
                                         !  output.
      INTEGER NFIDX(MTARGS)              !NFIDX is an array used to determine
                                         !  the index of the next at-
                                         !  tacker or defender to fire
                                         !  Entries into the NFIDX array
                                         !  are pointers into the
                                         !  PTEXIST and NUMTAR arrays.
      CHARACTER *2 NAMEOPF, NAMEIDF, NAMSDBF, NAMETDF, NAMEADF, IAIMDES,
     1        ITARDES
C
C     Initialize aiming error for each weapon type.
C
      DATA WCEP/0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 15.0, 1.12, 0.5,
     1        0.75, 0.75, 0.75, 0.75, 0.75, 0.75, 0.75, 0.75, 22.5,
     2        1.68, 0.75, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 30.0,
     3        2.24, 1.0/
C
C     Initialize firing rate for each weapon type.
C
      DATA WRATE/1.714, 6.316, 6.316, 0.343, 0.3, 0.109, 6.0, 0.109, 4.0,
     1        12.0, 0.133, 1.714, 6.316, 6.316, 0.343, 0.3, 0.109,
     2        6.0, 0.109, 4.0, 12.0, 0.133, 1.714, 6.316, 6.316, 3.0, 1.2,
     3        1.2, 6.0, 0.109, 4.0, 12.0, 0.133/
C
C     Initialize maximum weapon kill radius for each weapon type.
C
      DATA WMXKRAD/0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 5.0, 0.0, 0.0,
     1        0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 5.0, 0.0, 0.0,
     2        0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 5.0, 0.0, 0.0/
C
C     GINPUT is called to insure all data has been obtained for the simula-
C     tion and all probabilities of hit have been determined.
C
      CALL GINPUT
C
C     If an error occured while obtaining input, branch is taken to avoid
C     incorrect simulation results.
C
      IF (JERROR .NE. 0) GO TO 4100
C
C     Seed values for the random number generation routine RANDU are initial-
C     ized.
C
      ISEED1 = MSEED1
      ISEED2 = MSEED2
C
C     Initialize TMIN to begin the simulation.
C
```

```
      TMIN = 0.0
C
C     Set the next status change event time to greater than the total simula-
C     tion time. This value of STMIN is used if no status changes are neces-
C     sary.
C
      STMIN = TMAX+1.0
C
C     If status changes were specified, STATCHG is called to obtain the time
C     when the first status change occurs. This value is stored in STMIN.
C
      IF (NSTATCS .GT. 0) CALL STATCHG
C
C     TLRES is set to the point in time when simulation results were last
C     saved. This value is used in determining when to save the next set
C     of output results.
C
      TLRES = TSTART-DELTAT
C
C     ILRES is the number of simulation result sets saved.
C
      ILRES = 1
C
C     Initialize probability of existance and number of rounds fired for
C     each firer.
C
      DO 100 I = 1, NTARS
          PTEXIST(I) = 1.0
          NROUNDF(I) = 0
  100 CONTINUE
C
C     The following code section determines whether more than one firer is
C     scheduled to fire at the present instant in time. NMINEQ contains the
C     number of firers who are scheduled to fire.
C
C     Initialize NMINEQ to 1 firer.
C
200   NMINEQ = 1
C
C     Maximize the next firing time in TMIN. TMIN is used to obtain the
C     firing time for the next defender or attacker to fire.
C
      TMIN = TMAX+1.0
C
C     Loop for all firers to determine the firer or set of firers to fire.
C
      DO 500 I = 1, NTARS
C
C     The firing time for firer I, EVENTTM(I), is compared to TMIN, the
C     lowest firing time found so far.  If EVENTTM(I) is greater than TMIN,
C     no action is taken and this firer will not fire until later.  If
C     EVENTTM(I) is equal to TMIN, another firer has been found with a firing
C     equal to the minimum firing time previously found.  He will be consider-
C     ed as a candidate to fire at this time along with all other firers
C     having the same "next shot" firing time.  The index of this firer is
```

```
C         saved in the NFIDX array.  If EVENTTM(I) is less than the lowest firing
C         time found so far, this firer becomes the prime candidate to fire.  All
C         information concerning previous candidates is destroyed by setting
C         NMINEQ to 1.  The index of this firer is saved, and the TMIN value is
C         reduced to the firing time of this firer.
C
              IF (EVENTTM(I)-TMIN) 300, 400, 500
C
C         Set TMIN to the next minimum event time found thus far.
C
  300         TMIN = EVENTTM(I)
C
C         Set the number of firers found having firing times equal to the new
C         minimum event time to 1.
C
          NMINEQ = 1
C
C         Store the index of the firer having the new minimum event time into the
C         NFIDX array.
C
          NFIDX(1)=I
              GO TO 500
C
C             Increment the number of firers having minimum event time.
C
400           NMINEQ = NMINEQ+1
C
C         Branch back to top of loop if the event time for all firers has not
C         been checked.  After all firer's firing times have been compared, TMIN
C         will contain the minimum firing time, NFIDX will contain indicies of
C         all firers having this minimum firing time, and NMINEQ will contain the
C         number of firers with equal minimum firing times.
C
  500     CONTINUE
C
C         Determine whether the next set of results should be saved.
C
C         TLRES is the time at which the last set of results was saved.
C         DELTAT is the time difference between result output, hence TNRES is
C         the time at which the next set of results is to be saved.
C
  600     TNRES = TLRES+DELTAT
C
C         If the time of next result save is less than(or equal to) the time that
C         the next firing occurs, then results for the simulation at time TNRES
C         are saved as the current value in the PTEXIST array, since only firing
C         situations can effect PTEXIST values.
C
          IF (TNRES .GT. TMIN) GO TO 900
C
C         Save simulation results after TNRES units of time have elapsed in the
C         simulation.
C
          DO 700 I = 1, NTARS
              RESULTS(I, ILRES) = PTEXIST(I)
```

```
 700     CONTINUE
C
C        Increment the index into the results array to point to the location to
C        store results for next time increment.
C        ILRES = ILRES+1
C
C        Increment the time at which the next set of simulation results should
C        be obtained.
C
         TLRES = TNRES
         GO TO 600
C
C        If the time of the next firing is greater than the maximum time desired
C        for the simulation, branch to output results and end.
C
 800     IF (TMIN .GT. TMAX) GO TO 3200
C
C        If the time of the next status change is less than or equal to the time
C        at which the next player fires, perform the status change before
C        allowing the player to fire.
C
         IF (TMIN .LT. STMIN) GO TO 900
C
C        Maintain seed values so that varying the number of status changes, etc.
C        does not effect the selection of random numbers used by the main
C        program.
C
         ISEED1S = ISEED1
         ISEED2S = ISEED2
C
C        Perform status change.
C
         CALL STATCHG
C
C        If an error occured during the status change, branch and end execution.
C
         IF (JERROR .NE. 0) GO TO 4100
C
C        Reestablish possibly modified seed values.
C
         ISEED1 = ISEED1S
         ISEED2 = ISEED2S
C
C        Select the index of the next player to fire. Initially assume that
C        there is a single player who has a unique minimum response time. If
C        there is a unique player with minimum response time, the index of this
C        player would be the first element in the NFIDX array.
C
 900     NFIRER=NFIDX(1)
C
C        If only one firer is selected, branch. The firer's index is stored in
C        NFIRER.
C
         IF (NFIRED .EQ. 1) GO TO 1400
C
```

```
C       If there exists more than one player with equally minimum firing time,
C       then a selection must be made as to which of these players is to fire.
C       The methodology to select which of these players is to fire is based on
C       the primiss that each player has an equal chance of firing first.  A
C       uniform random number on the real interval (0,1) is selected.  This num-
C       ber is the transformed to the real interval (0,NMINEQ), where NMINEQ is
C       the number of players having equally minimum firing times, by multi-
C       plying the U(0,1) random variable by NMINEQ.  The U(0,NMINEQ) random
C       variable is then transformed to the interval (1,NMINEQ+1) by adding
C       1 to the U(0,NMINEQ) value.  Next, the U(1,NMINEQ+1) random variable
C       value is truncated obtaining the index into the NFIDX array of the
C       next player to fire.  The truncation is performed automatically by
C       assigning the real value between (1,NMINEQ+1) to an integer variable,
C       in this case NEXTF.
C
        CALL RANDU (ISEED1, ISEED2, U)
C
C       Obtain index to next firer, NEXTF, which is an integer number between
C       1 and NMINEQ.
C
        NEXTF=U*FLOAT(NMINEQ)+1.
C
C       Obtain index of player to fire in NFIRER. NUMTAR(NFIRER) is the actual
C       firer number.
C
        NFIRER=NFIDX(NEXTF)
C
C       Save the probability of existance array temporarily so that collateral
C       damage may be assessed corectly.
C
 1400   DO 1500 I = 1, NTARS
            PTEXSV(I) = PTEXIST(I)
 1500   CONTINUE
C
C       Obtain the probability(stored in PFIREX) that the firer which has been
C       selected to fire, is still around to fire(ie - PFIREX is the probabil-
C       ity that the firer has not been killed previously).
C
        PFIREX = PTEXIST(NFIRER)
C
C       PAIMC is the cumulative probability that the firer has selected an aim
C       point to fire at.
C
        PAIMC = 0.0
C
C       JJ is an index into the NAIMPRY array specifing a particular aim point
C       from the prioritized list of aim points the firer NFIRER may aim at.
C
        JJ = 1
C
C       The aim point number is stored in NAIMPT.  This is used to index into
C       the NTHITGA(Number of Targets HIT Given Aim point) and the PTARHIT(
C       Probability TARget is HIT) arrays.
C
 1600   NAIMPT = NAIMPRY(NFIRER, JJ)
```

```
C
C          NAIMPT=0 indicates all aim points that firer NFIRER has selected to fire
C          at have been evaluated.  The branch is taken, completing the 'perform
C          firing event code section'.
C
           IF (NAIMPT .EQ. 0) GO TO 3000
C
C          P is the probability that firer NFIRER has not fired at an aim point
C          investicated previously.
C
           P = 1.0-PAIMC
C
C          P=0. indicates that the firer, given he is still alive to fire, has
C          already selected aim points to fire at with probability equal to 1.
C          Thus, he will not fire at other possible aim points, and hence, the
C          branch is taken ending the 'perform firing process'.
C
           IF (P .EQ. 0.0) GO TO 3000
C
C          NTARGET in the number of the primary target associated with the aim
C          point whoose index is given by NAIMPT.
C
           NTARGET = NTHITGA(NAIMPT, 1)
C
C          The methodology used to determine the probability that the firer fires
C          at a particular aim point is outlined in the following text.
C
C          The target array is searched to find the index of NTARGET.  The index
C          to NTARGET is stored in ITARGT when found.  If not found, an error has
C          occured in defining target status change in input and an error message
C          is issued.
C
C          The following statements are used to determine the probability that a
C          particular aim point is chosen.
C
C          STMT 1) The probability that the primary target, associated with the
C                  the aim point the firer is firing at, exists(stored in PAIM),
C                  or
C
C          STMT 2) the probability that the firer has not fired at an aim point
C                  previously(stored in P).
C
C                  Each time a player is selected to fire, he will either select
C          one aim point to fire at or choose not to fire at any aim point be-
C          cause of high probability that each primary target has been destroyed
C          previously.  This concept may be expressed in terms of probability as
C          follows:
C
C          RULE 1) The probability that the firer either fires at one of the aim
C                  points in his prioritized aim point list or chooses not to fire
C                  must sum to 1.
C           Formally, the probability that the firer fires at a particular aim
C          point on his prioritized list of aim points is the probability that the
C          primary target associated with that aim point still exists(RULE 1).
C          Early in the simulation however, the probability that each of the pri-
```

mary targets(associated with the prioritized list of aim points that the firer is interested in) still exists is quite high.

Since the probability that he fires at each aim point is proportional to the probability that it's primary target exists(STMT 1), a probability that he selects one of the aim points in his prioritized list in could exceed 1. This violates the condition specified in RULE 1. Hence, STMT 2 is necessary to avoid the situation where the probability would exceed 1 for the firer selecting aim points in his prioritized list to fire at.

The following example illustrates in better detail how STMTs 1 and 2 are used in the simulation. Suppose a firer has the choice of firing at one of these possible prioritized aim points(A1, A2 or A3) or not to fire at all because the primary targets associated with each of these aim points may have been destroyed previously. The following table gives the probability that the primary targets T1, T2 and T3 (associated with aim points A1, A2 and A3 respectively) have not been previously destroyed.

T1	T2	T3
.5	.3	1.

In this example we will assume that the firer's strategy is to first fire at aim point A1 attempting to destroy target T1, and after T1 is destroyed, he will fire at aim point A2 attempting to destroy target T2, and so on. The probability that the firer chooses to fire at A1 is given by the minimum between PAIM(computed by STMT 1) and P(computed by STMT 2). PAIM as computed by STMT 1 for the primary aim point of interest, A1, would be:

PAIM=1.-.5, where .5 is the probability that the primary target (T1) associated with aim point A1 still exists. Thus, PAIM=.5 for aim point A1.

P, which is the probability that the firer has not fired at a previous aim point is initially 1, since this is the first aim point that may be chosen.

Thus, the probability that the firer chooses aim point A1 to fire at is given by the minimum of PAIM(.5) or P(1.). This probability, which is stored in the variable PFIREAP, is .5 for aim point A1. This leaves the firer with a maximum probability equal to .5 of being able to fire at aim point A2.

The PAIM value for firing at aim point A2 is the probability that the primary target associated with aim point A2 still exists(PAIM =.3 from table). P is the probability that he did not fire at A1(P=.5). Therefore the probability that aim point A2 is selected to be fired at is given by PFIREAP=.3.

The PAIM value for firing at aim point A3 is 1., obtained from the table. P is the probability that aim point A1 was not chosen and aim point A2 was not chosen, which is expressed by:

P=1-[.5(probability A1 selected) + .3(probability A2 selected)]=.2

PFIREAP is given as the minimum between PAIM=1. or P=.2. Thus,

```
C        the probability that aim point A3 is selected to be fired at is
C        PFIREAP=.2.
C
C                Notice that if we add the probabilities that the firer fires at
C        either A1, A2 or A3 we get 1.(ie - .5+.3+.2). This,however would not be
C        the case if the probability that primary target T3 existed was less
C        than .2. Then there would be a probability that neither aim point A1,
C        A2 or A3 would be selected(ie - the firer would not fire, since the
C        primary targets associated with aim points of interest to him would
C        have been destroyed previously. The following data summarizes the prob-
C        ability that each of the aim points A1, A2 or A3 were selected:
C
C                                A1     A2     A3
C                                .5     .3     .2
C
C                This ends the aim point selection description section.
C
         DO 1700 ITARGET = 1, NTARS
              IF (NUMTAR(ITARGET) .EQ. NTARGET) GO TO 1800
 1700    CONTINUE
         TYPE *, 'TARGET ', NTARGET, ' COULD NOT BE FOUND(3).'
         GO TO 4100
C
C        Get the probability that the primaty target associated with aim point
C        NAIMPT still exists, and store into PAIM.
C
 1800    PAIM = PTEXSV(ITARGET)
C
C        Determine whether to use PAIM or P as the probability NAIMPT is select-
C        ed to be fired at.
C
         IF (PAIM .GE. P) GO TO 1900
C
C        Set the probability of firing at this aim point to the probability that
C        the primary target associated with this aim point has not been destroy-
C        ed.
C
         PFIREAP = PAIM
C
C        Increment the cumulative probability that the firer has selected an aim
C        point previously by adding in the probability that this aim point was
C        selected.
C
         PAIMC = PAIMC+PFIREAP
         GO TO 2000
C
C        The probability that the firer fires at this aim point, PFIREAP, is the
C        remaining probability that he has not selected a aim point previously.
C
 1900    PFIREAP = P
C
C        In this situation, the firer has definitely selected an aim point from
C        those evaluated previously, hence PAIMC is set to 1.
C
         PAIMC = 1.0
```

The next section modifies the probability of existance array, PTEXIST, appropriately for all targets possibly effected by NFIRER firing at aim point NAIMPT.

At this point a firer, NFIRER, has been selected to fire, an aim point has been chosen, NAIMPT, and the probability that this aim point is fired at has been determined and is stored in PFIREAP. The effect of this event on the target existance probability for all targets which may be damaged will now be determined.

KK is used to index a particular target which may be hit by firing at aim point NAIMPT. KK is initially set to 1, specifying the first target(the primary target) associated with aim point NAIMPT. The actual target number corresponding to aim point NAIMPT and index KK is given by NTHITGA(NAIMPT,KK) and stored in NTARGET. The probability that the target specified by KK is hit when NFIRER fires at aim point NAIMPT is obtained from the PTARHIT array and stored in PTH.

The probability that this target still exists after NFIRER fires a shot at aim point NAIMPT is computed by multiplying:

1) the probability that the target has not been destroyed previously, from the PTEXIST array. (This is also the probability that this target exists before this shot is fired. For simplicity the phrase "this shot fired" will be used to avoid repetition of the phrase NFIRER fires a shot at aim point NAIMPT".) X

2) the probability that the target still exists after this shot is fired.

This is the probability that the target was not hit previously and continues to remain undamaged after this shot is fired.

The probability that the target still exists after this shot is fired is equal to:

1.-the probability that the target is hit by this shot.

The probability that the target is hit by this shot is expressed by multiplying:

1) the probability that the firer still exists to fire the shot (ie - he has not been killed previously), stored in PFIREX. X

2) the probability that, given the firer still exists(ie - can fire), he selects aim point NAIMPT to fire at, stored in PFIREAP. X

3) the probability that, given the firer still exists and he fires at aim point NAIMPT, he can hit the target, stored in PTH.

Collateral damage is assessed by decreasing the probability

```
C         that collaterally damaged targets exist by the probabilty this target
C         was hit.
C
C                 Initialize KK to point to the first target which may be hit by
C         firing at this aim point.
C
 2000     KK = 1
C
C         The probability that firer NFIRER aims at the JJth aim point in his set
C         of possible aim points and hits the KKth target which may be hit by
C         firing at this aim point is stored in PTH.
C
 2100     PTH = PTARHIT(NFIRER, JJ, KK)
C
C         If the probability of target hit is zero then branch to avoid modifica-
C         tion to PTEXIST array, since the probability of target existance will
C         not be effected.
C
          IF (PTH .EQ. 0.0) GO TO 2800
C
C         Obtain the number of the KKth target which may be hit by firing at the
C         aim point.
C
          NTARGET = NTHITGA(NAIMPT, KK)
C
C         If this target number is zero, all targets which may be hit by firing
C         at the aim point NAIMPT have been examined.  Branch is taken to modify
C         probability of target existance should the next aim point be selected.
C
          IF (NTARGET .EQ. 0) GO TO 2900
C
C         The probability that target NTARGET is not destroyed by NFIRER firing
C         a single shot at aim point NAIMPT in computed and stored in PTARDES.
C
          PTARDES = 1.0-PTH*PFIREX*PFIREAP
C
C         Determine the index of the next target NTARGET in the NUMTAR array.
C
          DO 2200 ITARGET = 1, NTARS
              IF (NUMTAR(ITARGET) .EQ. NTARGET) GO TO 2300
 2200     CONTINUE
          TYPE *, ' TARGET ', NTARGET, ' COULD NOT BE FOUND(1).'
          GO TO 4100
C         MM is used to determine the next target which will suffer collateral
C         damage should target NTARGET be hit. MM is set to 1 initially to select
C         the first collaterally damaged target associateed with destruction of
C         NTARGET.
C
 2300     MM = 1
C
C         Obtain the number of the collaterally damaged target in NCOLTAR.
C
 2400     NCOLTAR = NICOLAT(ITARGET, MM)
C
C         If NCOLTAR equals zero, all collateral damage targets associated with
```

```
C         destruction of target NTARGET have been processed, and branch to modify
C         probability of existance of NTARGET value, PTEXIST(ITARGET).
C
          IF (NCOLTAR .EQ. 0) GO TO 2700
C
C         Obtain the index of NCOLTAR in the NUMTAR array.
C
          DO 2500 ICOLTAR = 1, NTARS
              IF (NUMTAR(ICOLTAR) .EQ. NCOLTAR) GO TO 2600
 2500     CONTINUE
          TYPE *, 'TARGET ', NCOLTAR, ' COULD NOT BE FOUND(2).'
          GO TO 4100
C
C         Modify the probability that the collaterally damaged target NCOLTAR
C         exists by multplying it's previous existance probability by the prob-
C         ability that target NTARGET is not hit by this shot.  Collateral damage
C         is assessed to target NCOLTAR assuming that if target NTARGET is hit,
C         NCOLTAR will also suffer equal damage. The model does not presently
C         allow the user to input a probability of collateral damage to target
C         NCOLTAR if target NTARGET is hit. The probability that target NCOLTAR
C         is damaged if NTARGET is hit is 1.
C
 2600     PTEXIST(ICOLTAR) = PTEXIST(ICOLTAR)*PTARDES
C
C         MM is incremented to point to the next collaterally damaged target.
C
          MM = MM+1
C
C         If MM is less than the maximum number of targets which can be collater-
C         ally damaged by hitting target NTARGET, branch and process next collat-
C         erally damaged target, otherwise the probability of existance has been
C         modified for all collaterally damaged targets.
C
          IF (MM .LE. NTCOLAT) GO TO 2400
C
C         Modify the probability of existance for target NTARGET to reflect the
C         change in existance probability due to firing this shot.
C
 2700     PTEXIST(ITARGET) = PTEXIST(ITARGET)*PTARDES
C
C         Increment KK to point to the next target which may be hit by firing at
C         aim point NAIMPT.
C
 2800     KK = KK+1
C
C         If KK is greater than the maximum number of targets which can be hit by
C         firing at a given aim point, all targets have been processed for this
C         aim point, otherwise branch to modify all target existance probabil-
C         ities effected by hitting the next target associated with this aim
C         point.
C
          IF (KK .LE. MTHIGA) GO TO 2100
C
C         Increment JJ to point to the next aim point available to the firer for
C         selection.
```

```
C
 2900   JJ = JJ+1
C
C       If JJ is less than or equal to the maximum number of aim points permit-
C       ted for a given firer, branch and process next aim point, otherwise all
C       aim points that this firer may shoot at have been processed.
C
        IF (JJ .LE. MAIMPRY) GO TO 1600
C
C       NWT is a key indicating the type of weapon used by NFIRER, the player
C       who just fired the last round.
C
 3000   NWT = NWTYPE(NFIRER)
C
C       EVENTTM(NFIRER) is the time at which this player os expected to fire
C       his next round. The expected time to aim and fire the next shot stored
C       in the weapon firing rate array(WRATE), is added to the present value
C       of EVENTTM(NFIRER).
C
        EVENTTM(NFIRER) = EVENTTM(NFIRER)+WRATE(NWT)
C
C       The number of rounds fired by NFIRER is incremented.
C
        NROUNDF(NFIRER) = NROUNDF(NFIRER)+1
C
C       If NFIRER has run out of ammunition, a message is printed and the time
C       at which he fires his next shot and the firer's next shot event time
C       is set greater than the total simulation time to insure that he will
C       not fire again(unless he acquires more ammunition at a later date in
C       the simulation).
C
        IF (NROUNDF(NFIRER) .LT. NROUNDS(NFIRER)) GO TO 200
        WRITE (3, 3100) NFIRER, EVENTTM(NFIRER)
 3100   FORMAT (' FIRER: ', I3, ' RAN OUT OF AMMUNITION AFTER ', F10.2,
        1            ' SECONDS.')
        EVENTTM(NFIRER) = TMAX+1.0
        GO TO 200
C
C       The simulation is complete with probability of existance results stored
C       for all targets at each DELTAT time interval in the RESULTS array.
C
C       Decrement ILRES to the exact number of time interval "snap shots" saved
C       in the RESULTS array.
C
 3200   ILRES = ILRES-1
C
C       Fill the RTIME array with the time at which each "snap shot" of target
C       existance probabilities was taken.
C
        RTIME(1) = TSTART
        DO 3300 I = 2, ILRES
            RTIME(I) = RTIME(I-1)+DELTAT
 3300   CONTINUE
        JT = 2*NTITLEL+2
C
```

```
C
C       Frame the title with '*'s.  Output first row of '*'s.
C
        WRITE (3, 3400) ('*', I = 1, JT)
 3400   FORMAT (X, <JT>A1)
C
C       Output simulation title with '*'s before and after each line.
C
        DO 3600 I = 1, NTITLES
            WRITE (3, 3500) (ITITLE(I, J), J = 1, NTITLEL)
 3500       FORMAT (1X, '*', <NTITLEL>A2, '*')
 3600   CONTINUE
C
C       End simulation title with row of '*'s.
C
        WRITE (3, 3400) ('*', I = 1, JT)
        WRITE (3, 3700)
 3700   FORMAT (//)
C
C       Write top output heading which contains time at which probability of
C       existance results are saved in increments of DELTAT time units.
C
        WRITE (3, 3800) (RTIME(I), I = 1, ILRES)
 3800   FORMAT (' TIME ELAPSED=', F5.1, 19(1X, F5.0))
C
C       Loop to print the probability of existance results for all targets.
C
        DO 4000 I = 1, NTARS
C
C       Print probability of existance results for the next target, all time
C       intervals.
C
            WRITE (3, 3900) I, (ITARDES(I, J), J = 1, 5), (RESULTS(I, J), J =
        1               1, ILRES)
 3900       FORMAT (1X, I3, 5A2, F5.3, <ILRES-1>(1X, F5.3))
 4000   CONTINUE
C
C       Call CONDPRO fo combine probability of existance values into expected
C       number of targets left with time. The user has the capability to clas-
C       sify certain targets into groups for analysis by the CONDPRO  subrou-
C       tine. A user for example may wish to group all attacker personnel tar-
C       gets into one group enabling observation of the expected number of at-
C       tack personnel remaining with time.
C
        CALL CONDPRO
C
C       Close input data file.
C
 4100   CLOSE (UNIT = 1)
C
C       Close data base file containing probabilities of hit.
C
        CLOSE (UNIT = 2)
C
C       Close output data file containing expected target existance probabil-
C       ities.
```

```
C
      CLOSE (UNIT = 3)
C
C     Close target data base file.
C
      CLOSE (UNIT = 4)
C
C     Close aim point data base file.
C
      CLOSE (UNIT = 7)
      STOP
      END
      SUBROUTINE CONDPRO
C
C             CONDPRO -- A VAX/VMS FORTRAN subroutine which calculates
C     conditional probabilities, written for JAYCOR by Joe Humphrey,
C     Mar 1980.
C
C             ITGROUP contains a number of groups of targets, each of
C     which has a probability of being destroyed (In RESULTS).  For
C     each group, the conditional probability that i targets are
C     destroyed, as i goes from 0 to the number of targets in the
C     group, are calculated and written to unit 3.  This is done
C     for several times of interest (TSTART, TSTART+DELTAT,
C     TSTART+2*DELTAT, . . ., TSTART+(ILRES-1)*DELTAT).


C     Define constants and variables.

      INCLUDE '*.INC'

      PARAMETER OUT = 3             ! Unit number of output file

      CHARACTER *2 ITARDES(MTARGS, 5) ! Target descriptors

      INTEGER FIRST                 ! Pointer to last destroyed target,
C                                   !- after trailing destroyed targets
C                                   !- have been restored (E. G. If KILLED
C                                   !- = FFTTFFTTT, FIRST = 4)
      INTEGER GIND                  ! Index to target in ITGROUP
      INTEGER GROUP                 ! Index to group in ITGROUP
      INTEGER GTIND(MTARGS)         ! Conversion from GIND to TIND
      INTEGER ILRES                 ! Number of time increments
      INTEGER ITGROUP(MTARGS, MGROUPS)! Target numbers of targets in groups
      INTEGER LAST                  ! Pointer to last destroyed target
      INTEGER LENGTH                ! Number of trailing destroyed targets
C                                   !- (E. G. If KILLED = FFTTFFTTT,
C                                   !- LENGTH = 3)
      INTEGER NDEST                 ! Number of targets to be destroyed
      INTEGER NTARGS                ! Number of targets in group
      INTEGER NUMTAR(MTARGS)        ! Conversion from TIND to target
C                                                           !- number
      INTEGER TINC                  ! Number of time increments passed
      INTEGER TIND                  ! Index to target in target array
C                                           !- (RESULTS, TARNUM, etc.)
      INTEGER WORD                  ! Pointer to word of ITARDES

      LOGICAL KILLED(MTARGS)        ! .TRUE. if the corresponding target
C                                   !- in ITGROUP is destroyed; .FALSE.
C                                   !- otherwise

      REAL DELTAT                   ! Length of time increment (seconds)
      REAL EPROB                    ! Probability of an event (A
C                                   !- particular configuration of KILLED)
      REAL EXPNDES(MTMINTS)         !
      REAL GPROB(MTMINTS)           ! Probability of a group of events (E.
C                                   !- G. that 1 target is destroyed in
C                                         !- ITGROUP)
        REAL RESULTS(MTARGS, MTMINTS)     ! Probabilities that a target will be
C                                         !- around after so many time increments
        REAL TSTART                       ! Starting time

        COMMON /L6/ NUMTAR, /L7/ ITARDES, /L17/ RESULTS, /L24/ DELTAT, /L44/
        1       TSTART, /L46/ ITGROUP, /L47/ ILRES

C
C       Find number of targets in group, converting GINDs to TINDs.
C       Return if 0 targets in group.

        DO 2600 GROUP = 1, NGROUPS
            DO 100 TINC = 1, ILRES
                EXPNDES(TINC) = 0.0
 100        CONTINUE
            DO 400 GIND = 1, MTARGS
                IF (ITGROUP(GIND, GROUP) .LE. 0) GO TO 500
                DO 200 TIND = 1, MTARGS
                    IF (ITGROUP(GIND, GROUP) .EQ. NUMTAR(TIND)) GO TO 300
 200            CONTINUE
                TYPE *, 'Target', ITGROUP(GIND, GROUP), ' in ITGROUP not '//
        1               'found.'
                CALL EXIT

 300            GTIND(GIND) = TIND
 400        CONTINUE
            GIND = MTARGS+1
 500        NTARGS = GIND-1
            IF (NTARGS .LE. 0) GO TO 2700

C
C           Write title, target numbers and descriptors, and times of
C           interest.

            IF (GROUP .EQ. 1) WRITE (OUT, 600)
 600        FORMAT ('1')
            WRITE (OUT, 700) GROUP, (NUMTAR(GTIND(GIND)),
        1           (ITARDES(GTIND(GIND), WORD), WORD = 1, 5), GIND = 1,
        2           NTARGS)
 700        FORMAT (///X, 'CONDITIONAL PROBABILITIES FOR GROUP #', I1,
        1               ', CONSISTING OF TARGETS:'/, (X, 9(I3, X, 5A2)))
            WRITE (OUT, 800) (TSTART+FLOAT(TINC-1)*DELTAT, TINC = 1, ILRES)
 800        FORMAT (/X, 3X, <ILRES>(X, F5.1))

C
C           Start out with no targets destroyed.  Write number of targets
C           to be destroyed.  Initialize group probability.

            DO 900 GIND = 1, NTARGS
                KILLED(GIND) = .FALSE.
 900        CONTINUE

            DO 2300 NDEST = 0, NTARGS

                DO 2000 TINC = 1, ILRES
                    GPROB(TINC) = 0.0
```

```
C                       Find event probability.  Sum into group probability.

 1000                   EPROB = 1.0
                        DO 1100 GIND = 1, NTARGS
                            IF (KILLED(GIND)) THEN
                                EPROB = EPROB*(1.0-RESULTS(GTIND(GIND), TINC))
                            ELSE
                                EPROB = EPROB*RESULTS(GTIND(GIND), TINC)
                            END IF
 1100                   CONTINUE
                        GPROB(TINC) = GPROB(TINC)+EPROB

C                       Find last target destroyed.  If not at end of list,
C                       restore that target and destroy the next one.

                        DO 1200 LAST = NTARGS, 1, -1
                            IF (KILLED(LAST)) GO TO 1300
 1200                   CONTINUE
                        LAST = NTARGS
 1300                   IF (LAST .LT. NTARGS) THEN
                            KILLED(LAST) = .FALSE.
                            KILLED(LAST+1) = .TRUE.
                            GO TO 1000
                        END IF

C                       Last target destroyed -- find number of targets
C                       destroyed at end of list.  Restore those targets.

                        DO 1400 GIND = LAST, 1, -1
                            IF (.NOT. KILLED(GIND)) GO TO 1500
                            KILLED(GIND) = .FALSE.
 1400                   CONTINUE
                        GIND = 0
 1500                   LENGTH = LAST-GIND

C                       Find last destroyed target in revised list.  If none
C                       are destroyed, then all events for that number of
C                       destroyed targets have been found -- find it for next
C                       time increment.

                        DO 1600 FIRST = LAST, 1, -1
                            IF (KILLED(FIRST)) GO TO 1800
 1600                   CONTINUE
                        IF (LENGTH .GT. 0) THEN
                            DO 1700 GIND = 1, LENGTH
                                KILLED(GIND) = .TRUE.
 1700                       CONTINUE
                        END IF
                        GO TO 2000

C                       Destroyed target found -- restore it, destroy next
C                       LENGTH+1 targets, and find event probability.

 1800                   KILLED(FIRST) = .FALSE.
                        DO 1900 GIND = FIRST+1, FIRST+LENGTH+1
```

```
                       KILLED(GIND) = .TRUE.
 1900              CONTINUE
                   GO TO 1000
 2000          CONTINUE
C
C              Group probabilities for all times of interest have been
C              found (for NDEST destroyed targets).  Write them and find
C              group probabilities for NDEST+1 destroyed targets.

               IF (LENGTH .LT. NTARGS) KILLED(LENGTH+1) = .TRUE.
               WRITE (OUT, 2100) NDEST, (GPROB(TINC), TINC = 1, ILRES)
 2100          FORMAT (X, I3, X, <ILRES>(X, F5.3))
               IF (NDEST .GT. 0) THEN
                   DO 2200 TINC = 1, ILRES
                       EXPNDES(TINC) = EXPNDES(TINC)+GPROB(TINC)*NDEST
 2200              CONTINUE
               END IF
 2300      CONTINUE
           WRITE (OUT, 2400)
 2400      FORMAT (//X, ' EXPECTED NUMBER OF TARGETS DESTROYED AFTER',
      1                 ' TIME ELAPSED:')
           WRITE (OUT, 800) (TSTART+FLOAT(TINC-1)*DELTAT, TINC = 1, ILRES)
           WRITE (OUT, 2500) (EXPNDES(TINC), TINC = 1, ILRES)
 2500      FORMAT (4X, <ILRES>(X, F5.2))
 2600  CONTINUE

C      All probabilities found -- return.

 2700  RETURN
       END
      SUBROUTINE GETPTH
C
C     PURPOSE - Determine the probability that firer NF fires at aim point
C               NAM and hits target NT.  The probability of hit is returned in
C               PTH.  The routine is based on a Monte-Carlo sampling technique
C               which fires a number of shots at a target, counting the num-
C               ber of hits which occured.  The number of hits is divided by
C               the number of tries and a probability of hit is obtained.
C               Aimming error is defined in terms of a radius(contained in
C               array WCEP) within which 1/2 of all shots are expected to
C               land.  The radius in which 1/2 of the shots land defines a
C               Raleigh distribution with mean equal to the radius, r.  In
C               orded to generate random shots from the Raleigh distribution,
C               the model first draws random numbers from a uniform distri-
C               bution, then converts these to normal random variables.  The
C               normal random variables are then used as absolute X and Y
C               offsets from the intended aim point for a particular shot.
C               The miss distance from the aim point is expressed as:
C
C                              DIST=SQRT(X*X+Y*Y)
C
C               In order to generate normal random variables for the X and Y
C               offsets, the normal distribution from which these variables
C               are drawn must provide random variables X and Y which
C               satisfy the assumption that 1/2 the time the distance, given
C               by SQRT(X*X+Y*Y), is < or = r.  The mean for each X and Y ran-
C               dom variable is zero, since it is just as likly to be off
C               high as it is low.  It can be shown mathematically that the
C               variables X and Y drawn from a N(0,r*.8493) (a normal dist-
C               tribution with mean=0, variance=r*.8493) will satisfy SQRT(
C               X*X+Y*Y) < or = r 50% of the time, where r is the distance
C               from the aim point in which 50% of all shots fired are expec-
C               ted to land.
C               The model presently accepts targets only rectangular in
C               shape, however, by using the Monte-Carlo sampling technique,
C               any target shape may be used, provided the code is written to
C               determine whether the shots fired lie within the target area
C               or outside the target area.
C               This routine also evaluates situations where random aim areas
C               are used instead of fixed aim points.  When random aim areas
C               are used, shots are fired at aim points selected uniformly
C               from a rectangular region whose coordinates are defined by
C               the analysist.  Each time a new shot is to be fired, a new aim
C               point for the shot is selected at random from within the
C               area.
C               The number of shots fired in determining the probability of
C               hit may be modified by changing the value of MSHOTS in the
C               include file W.INC.
C
      INCLUDE 'W.INC'
      COMMON /L1/ WCEP(NWTYPES)
      COMMON /L6/ NUMTAR(NTARGS)
      COMMON /L7/ ITARDES(NTARGS, 5)
      COMMON /L8/ TARCHAR(NTARGS, 6)
      COMMON /L9/ NWTYPE(NTARGS)
```

```
          COMMON /L13/ NUMAIMP(MAIMPTS)
          COMMON /L14/ IAIMDES(MAIMPTS, 5)
          COMMON /L15/ AIMCHAR(MAIMPTS, 4)
          COMMON /L21/ ISEED1, ISEED2
          COMMON /L29/ NF
          COMMON /L30/ NAM
          COMMON /L31/ NT
          COMMON /L32/ PTH
          COMMON /L39/ IDXFIR
          COMMON /L41/ IDXAIM
          COMMON /L45/ IDXTAR
          COMMON /L48/ WPXKRAD(NWTYPES)
          CHARACTER *2 ITARDES, IAIMDES
C
C         NHIT is used to accumulate the number of hits on target NT as the shots
C         are fired.
C
  300     NHIT = 0
C
C         The seed values are saved on input and restored on completion so that
C         modifing the numbers of shots fired will not effect the sequence of
C         random numbers generated in other sections of the code.
C
          ISSED1 = ISEED1
          ISSED2 = ISEED2
C
C         NSHOT is used to accumulate the total number of shots fired.
C
          NSHOT = 0
C
C         NW is set to a key identifying the firer's weapon type.
C
          NW = NWTYPE(IDXFIR)
C
C         WPRAD is the weapon kill radius. This is a lethal radius in which the
C         effects of the weapon fired will destroy the target.
C
          WPRAD = WPXKRAD(NW)
C
C         CEP is the radius, converted to apply to a circular normal distribu-
C         tion, within which one-half of all shots fired are expected to land.
C
          CEP = WCEP(NW)*0.8493
C
C         XLFC - X coordinate of Lower left Firer Corner. X coordinate of lower
C                left corner defining fixed position of firer. This value is
C                used as the X coordinate of the lower left corner of a random
C                area in which the firer may be located, if a random area for the
C                firer's position is specified(specified by FRAHGT>0.).
C
          XLFC = TARCHAR(IDXFIR, 3)
C
C         YLFC - Y coordinate of Lower left Firer Corner. Y coordinate of lower
C                left corner defining fixed position of firer. This value is
C                used as the Y coordinate of the lower left corner of a random
```

```
C                area in which the firer may be located, if a random area for the
C                firer's position is specified(specified by FRAHGT>0.).
C
      YLLC = TARCHAR(IDXFIR, 4)
C
C     FRAHGT - Firer Random Area Height. A random area is a rectangular area
C                in which the firer may be located. The position of the firer
C                is assumed equally likely any where within the random area.
C
      FRAHGT = TARCHAR(IDXFIR, 5)
C
C     FRAWID - Firer Random Area Width. Width of a rectangular area in Which
C                firer is located.
C
      FRAWID = TARCHAR(IDXFIR, 6)
C
C     Determine whether a random or fixed firer area was specified. The
C     branch is taken if a random area is desired.
C
      IF (FRAHGT .NE. 0.0) GO TO 500
C
C     Set the firer width and height for a fixed firer position.
C
      FWIDTH = TARCHAR(IDXFIR, 2)
      FHEIGHT = TARCHAR(IDXFIR, 1)
C
C     Compute the center of the firer's area with respect to width(FWD2 -
C     Firer Width Divided by 2).
C
  400 FWD2 = FWIDTH/2.0
C
C     Compute the center of the firer's area with respect to height(FWD2 -
C     Firer Height Divided by 2).
C
      FHD2 = FHEIGHT/2.0
C
C     XFCTR - X coordinate of Firer Center. Absolute position from origin of
C               of firer's center in X direction within firer's reference
C               plane. If a random firer area is specified, the center of the
C               firer is assumed to be the center of the random aim area.
C
      XFCTR = XLLC+FWD2
C
C     YFCTR - Y coordinate of Firer CenTeR. Absolute position from origin of
C               firer's center in Y direction within firer's reference plane.
C               The point (XFCTR,YFCTR) is assumed to be the point at which all
C               shots are fired from in the firer's reference plane.
C
      YFCTR = YLLC+FHD2
      GO TO 600
C
C     Use random firer area width to determine expected point from which
C     shots are fired from.  Shots are expected to be fired from the center
C     of the random area.
C
```

```
 500    TWIDTH = FRAWID
C
C       Use random firer area height to determine expected point from which
C       shots are fired from.
C
        FHEIGHT = FRAHGT
        GO TO 400
C
C       RAIMHGT - Random AIM point area HeiGhT.  The random aim point area is a
C                 rectangular area in which the firer is expected to aim.
C                 Before each shot is fired an aim point is selected from this
C                 area at random assuming all points within this area are as-
C                 sumed equally likely.
C
 600    RAIMHGT = AIMCHAR(NAM, 3)
C
C       RAIMWID - Random AIM point area WIDth.
C
        RAIMWID = AIMCHAR(NAM, 4)
C
C       XALC - X coordinate of random Aim point area Lower left Corner.  If a
C              fixed aim point is used, this is the Y coordinate of the fixed
C              aim point in the target reference plane.
C
        XALC = AIMCHAR(NAM, 1)
C
C       YALC - Y coordinate of random Aim point area Lower left Corner.  If a
C              fixed aim point is used, this is the Y coordinate of the fixed
C              aim point in the target reference plane.
C
        YALC = AIMCHAR(NAM, 2)
C
C       THEIGHT - Height of rectangular target area.
C
        THEIGHT = TARCHAR(NT, 1)
C
C       TWIDTH - Width of rectangular target area.
C
        TWIDTH = TARCHAR(NT, 2)
C
C       Obtain the center of rectangular target area with respect to height(
C       THD2 - Target Height Divided by 2).
C
        THD2 = THEIGHT/2.0
C
C       Obtain the center of rectangular target area in terms of width(TWD2 -
C       Target Width Divided by 2).
C
        TWD2 = TWIDTH/2.0
C
C       TRAHGT - Target Random Area HeiGhT.  The random target area is a rec-
C                tangular area in which the target itself is positioned.  The
C                position of the target within the random area is selected as-
C                suming each possible position is equally likely.
C
```

TRAHGT = TARCHAR(NT, 5)

XLTC - X coordinate of the Lower left Target Corner. Normally, XLTC is
 is the X coordinate of lower left corner defining a fixed target
 position. If a random target area is specified, this is the X
 coordinate of the lower left corner of the random target area.

XLTC = TARCHAR(NT, 3)

YLTC - Y coordinate of the Lower left Target Corner. Normally, YLTC is
 the Y coordinate of lower corner defining a fixed target position. If a random target area is specified, this is the Y coordinate of the lower left corner of the random target area.

YLTC = TARCHAR(NT, 4)

XCTRRTA - X coordinate for the CenTeR of the Random Target Area.
 TARCHAR(NT,6) is the width of the random target area.

XCTRRTA = TARCHAR(NT, 6)-TWIDTH

YCTRRTA - Y coordinate for the CenTeR of the Random Target Area. The
 point (XCTRRTA,YCTRRTA) is the center of the random target
 area relative to the origin in the target reference plane.

YCTRRTA = TRAHGT-THEIGHT

XTCTR - X coordinate of Target CenTeR.

XTCTR = TW/2+XLTC

YTCTR - Y coordinate of Target CenTeR. The point (XTCTR,YTCTR) is the
 center of the target area relative to the origin in the target
 reference plane.

YTCTR = TH/2+YLTC

Compute the distance from the firer(point where the shot is fired) and the target center if the firer is projected into the target reference plane.

XYDIST = SQRT((XFCTR-XTCTR)**2+(YFCTR-YTCTR)**2)

Compute the absolute distance between the firer(point where shot is fired) and target center by including the separation distance between reference planes.

DIST = SQRT(XYDIST**2+YSEPDIS**2)

The distance factor, DFACTOR, is used to modify the radius in which 1/2 of all shots are expected to land(CEP). The distance factor is computed by taking the ratio of absolute distance to the reference plane separation distance, since the CEP value was determined using the plane separation distance.

```
      DFACTOR = DIST/MSEPDIS
C
C     SIGMA is modified by the distance factor to generate random hit points
C     which are expected to fall within a circle with increased radius pro-
C     portional to the increase in distance between the firer and target nor-
C     malized by the plane separation distance.
C
      SIGMA = CEP*DFACTOR
C
C     SIGMAF is used to store the value of 2*SIGMA**2 for optimization
C     reasons, preventing this calculation from being re-evaluated several
C     times when it is later used to find the hit point for this shot.
C
      SIGMAF = -2.*SIGMA*SIGMA
C
C     XAIMCOR - X AIM point COORdinate value relative to the target reference
C                     plane origin.
C
      XAIMCOR = AIMCHAR(NAM, 1)
C
C     YAIMCOR - Y AIM point COORdinate value relative to the target reference
C                     plane origin.  For a fixed aim point, XAIMCOR and YAIMCOR are
C                     the coordinate values of the fixed aim point.  If a random
C                     aim area is desired, XAIMCOR and YAIMCOR will be redefined
C                     before they are used by selecting a random aim point from
C                     the random aim area.
C

C
      YAIMCOR = AIMCHAR(NAM, 2)
C
C     Increment the number of shots firer to indicate firing next shot.
C
 1100 NSHOT = NSHOT + 1
C
C     If we have exceeded the maximum number of shots necessary, the prob-
C     ability of hit can be determined and the branch is taken.
C
      IF (NSHOT .GT. NSHOTS)  GO TO 1700
C
C     If a fixed aim point is used, RAIMHGT=0 and branch is taken, otherwise
C     compute new aim point coordinates from random aim point area.
C
      IF (RAIMHGT .EQ. 0.0) GO TO 1200
C
C     Obtain new aim point X coordinate from random aim area.  Select a point
C     uniformly from the width of the random aim point area(RAIMWID) and add
C     the absolute position of the lower left corner of the random area.
C
      CALL RANDU (ISEED1, ISEED2, U)
      XAIMCOR = U*WIDTH+XALC
C
C     Obtain new Y coordinate from random aim point area.
C
      CALL RANDU (ISEED1, ISEED2, U)
      YAIMCOR = U*HEIGHT+YALC
C
C     If a fixed target area was specified(TRAHGT=0), the point (XTCTR,YTCTR)
C     already identifies the location of the lower left corner of the fixed
C     target area relative to the origin in the target reference plane.  If a
C     random target area was desired, values for XTCTR and YTCTR are reas-
C     signed in the following section before the next shot is fired.
C
 1200 IF (TRAHGT .EQ. 0.0) GO TO 1300
C
C     Compute new X coordinate for lower corner of target in random target
C     area.  The X coordinate of the lower left corner is selected randomly
C     from a line segment whoose length is given by the width of the random
C     target area minus the width of the target area.  This places the lower
C     left coordinate relative to the lower left corner of the random target
C     area.  To obtain the center of the target relative to the lower left
C     corner of the random target area, one-half the target width is added
C     (TWD2).  Finally, to place the X coordinate of the target center rela-
C     tive to the origin of the target reference plane, the lower left corner
C     of the random target area(XLTC) is added.
C
      CALL RANDU (ISEED1, ISEED2, U)
      XTCTR = U*XCTRRTA+TWD2+XLTC
      CALL RANDU (ISEED1, ISEED2, U)
C
C     The new Y coordinate for the target center is obtained in a similar
C     fashion independantly.  The point (XTCTR, YTCTR) now contains the
C     position of the recently placed target area relative to the origin
C     in the target reference plane.
C
      YTCTR = U*YCTRRTA+THD2+YLTC
      XYDIST = SQRT((XFCTR-XTCTR)**2+(YFCTR-YTCTR)**2)
C
C     Now that the new target position has been determined, the distance
C     between the firer and target center is computed, the distance factor
C     is obtained, and SIGMA redefined for the possible change in separ-
C     ation distance from the previous target position.  This allows a new
C     sigma factor, SIGMAF, to be used in obtaining the coordinates for the
C     next shot.
C
      DIST = SQRT(XYDIST**2+MSEPDIS**2)
      DFACTOR = DIST/MSEPDIS
      SIGMA = CEP*DFACTOR
      SIGMAF = -2.*SIGMA*SIGMA
C
C     At this point, the distribution for shots fired at the target has
C     been determined(by calculating the distribution variance stored in
C     SIGMA), the aim point has been determined(stored in XAIMCOR, YAIMCOR),
C     and the target has been positioned(center of target in XTCTR, YTCTR).
C     We "fire the shot" by selecting two uniform random variables(U1 and
C     U2) from the real interval (0.,1.).  These values are then converted
C     to two normal random variables (X and Y) having mean=0., variance=
C     SIGMA**2 via the transformation:
C
C       X=mean+SQRT(-2*variance*LOG(U1))*COS(2*pi*U2)
```

```
C
C         Y=mean+SQRT(-2*variance*LOG(U1))*SIN(2*pi*U2)
C
C         where pi=3.1459
C
C       NOTE - This techinque for generating normal variates from the uniform
C              distribution is described in the book: "Concepts and Methods in
C              Discrete Event Digital Simulation", by George S. Fishman, P. 213.
C
 1300   CALL RANDU (ISEED1, ISEED2, U)
        IF (U .GT. 0.9999) U = 0.9999
        IF (U .LT. 0.0001) U = 0.0001
        SQ = SIGMAF*ALOG(U)
        CALL RANDU (ISEED1, ISEED2, U)
        XSHOT = XAIMCOR+SQRT(SQ)*COS(6.28319*U)
C       CALL RANDU (ISEED1, ISEED2, U)
C       It is necessary when evaluating the ALOG function that the U(0,1)
C       value does not approach zero to closely, as the function is undefined
C       at that point.  It is also necessary that the U(0,1) value not
C       approach 1. to closely as this would result eventually in the square
C       root of a number very close to zero.
C
        IF (U .GT. 0.9999) U = 0.9999
        IF (U .LT. 0.0001) U = 0.0001
        SQ = SIGMAF*ALOG(U)
        CALL RANDU (ISEED1, ISEED2, U)
        YSHOT = YAIMCOR+SQRT(SQ)*SIN(6.28319*U)
C
C       The point (XSHOT, YSHOT) is the point at which the shot hits in the
C       target reference plane relative to the target origin.  If the X coor-
C       dinate of the shot falls to the left of the left side of the target,
C       or to the right side of the target, the shot misses and the branch is
C       taken to prevent registering a direct hit.
C
        IF (XSHOT .LT. XTCTR-TWD2 .OR. XSHOT .GT. XTCTR+TWD2) GO TO 1600
C
C       If the Y coordinate is below the bottom of the target, or above the
C       top of the target, the shot misses, and the branch is taken to avoid
C       registering a direct hit.
C
        IF (YSHOT .LT. YTCTR-THD2 .OR. YSHOT .GT. YTCTR+THD2) GO TO 1600
C
C       The shot has hit the target area.  The number of target hits is incre-
C       mented.
C
 1500   NHIT = NHIT+1
C
C       Branch to fire next shot.
C
        GO TO 1100
C
C       This shot has missed the target, however, depending on its proximity
C       to the target, may inflict enough damage to the target to register a
C       hit.  If the target center is within the lethal radius of the weapon
```

```
C        round, a hit is registered.
C
 1600    IF (WKRAD .EQ. 0.0) GO TO 1100
C
C        Compute the Distance From HIT CenTeR(DFHTCTR).
C
         DFHTCTR = SQRT((XSHOT-XTCTR)**2+(YSHOT-YTCTR)**2)
C
C        If the distance from the hit point is within the weapons lethal kill
C        radius, the branch is taken to register a hit.
C
         IF (DFHTCTR .LE. WKRAD) GO TO 1500
C
C        The shot has landed outside the maximum lethal weapon radius, branch
C        to fire next shot.
C
         GO TO 1100
C
C        Compute the probability of hit by dividing the number of hits by the
C        number of shots fired.
C
 1700    PTH = FLOAT(NHIT)/FLOAT(NSHOTS)
C
C        Output the firer number identifier, aim point number/identifier, tar-
C        get number/identifier and probability of hit.  Should unexplained
C        results be found when examining the simulation output, it is often
C        useful to view the probabilities of hit to locate possible errors in
C        input data.  For a large simulation there may be a considerable number
C        of probabilities printed.  Should this statement generate too much
C        output, the user may choose to make this statement a comment(by
C        placing a 'C' in column 1) without affecting the simulation results.
C
         WRITE (3, 1900) NF, (ITARDES(IDXFIR, I), I = 1, 5), NUMAIMP(NAM),
         1       (IAIMDES(NAM, I), I = 1, 5), NUMTAR(NT), (ITARDES(NT, I), I =
         2       1, 5), PTH
 1900    FORMAT (3(3X, I3, 1X, 5A2), 5X, F10.7)
         RETURN
         END
```

SUBROUTINE GINPUT

PURPOSE - The main purpose of the GINPUT subroutine is to get all necessary input needed to perform the SAS simulation. This includes all input in the input data file, the aim point data file and the target data file. An attempt is made to read each of these files. If all information has not been stored in these files previously, it will be obtained interactively. This routine also allows interactive modification of data contained within these files. This permits the user to set up the data to perform analysis of a baseline situation, then modify certain elements of the data to define an improvent option, for example, easily due to the interactive method of data entry and retrival.

The GINPUT routine is also used to initialize the aim point, target and probability of hit data base files and to make sure correct probabilities of hit have been obtained for all targets in their initial positions.

```
INCLUDE 'A.INC'
COMMON /L4/ PTEXIST(MTARGS)
COMMON /L5/ EVENTTM(MTARGS)
COMMON /L6/ NUMTAR(MTARGS)
COMMON /L7/ ITARDES(MTARGS, 5)
COMMON /L8/ TARCHAR(MTARGS, 6)
COMMON /L9/ MTYPE(MTARGS)
COMMON /L10/ GROUPOS(MTARGS)
COMMON /L11/ MAIMPRY(MTARGS, MAIMPRY)
COMMON /L12/ MTCOLAT(MTARGS, MTCOLAT)
COMMON /L13/ NUMAIMP(MAIMPTS)
COMMON /L14/ TAIMDES(MAIMPTS, 5)
COMMON /L15/ AIMCHAR(MAIMPTS, 4)
COMMON /L16/ MTHITGA(MAIMPTS, MTHITGA)
COMMON /L18/ PTARHIT(MTARGS, MSTMPRY, MTHITGA)
COMMON /L19/ NAMEOFF(5)
COMMON /L20/ NAMEIDF(5)
COMMON /L21/ NAMEOHF(5)
COMMON /L22/ JERROR
COMMON /L23/ TMAX
COMMON /L24/ DELTAT
COMMON /L25/ NTARS
COMMON /L26/ NAIMS
COMMON /L27/ ISEED1, ISEED2
COMMON /L28/ GROUPOF(MTARGS)
COMMON /L29/ NF
COMMON /L30/ NAA
COMMON /L31/ NT
COMMON /L32/ PTH
COMMON /L33/ NAMETOF(5)
COMMON /L34/ NAMEACH(5)
COMMON /L36/ ISTATUS(MSTATC, 2)
COMMON /L37/ STATUS(MSTATC, 2)
COMMON /L38/ NSTATCS
COMMON /L39/ IOXFIR
```

```
      COMMON /L40/ NTMA
      COMMON /L41/ IDXAIM
      COMMON /L44/ TSTART
      COMMON /L45/ IDXIAR
      COMMON /L46/ ITGROUP(NTARGS, NGROUPS)
      COMMON /L49/ ITITLE(NTITLES, NTITLEL)
      COMMON /L50/ NTITLES
      CHARACTER *1 ICHAR, IDEBUG, ISCHAR
      CHARACTER *2 NAMEOPF, NAMEIDF, NAMEDBF, NAMETDF, NAMEADF, IAIMDFS,
      1        ITARDES
      CHARACTER *10 NDBF, NTDF, NADF, NOPF, NIDF
C
C     The names of various input and output files used by the SAS model are
C     described as follows.  Each file name may be at most 10 characters in
C     length.
C
C             NDBF - Name for probability of hit data base file.
C             NTDF - Name of target data base file.
C             NADF - Name of aim point data base file.
C             NOPF - Name of output file.
C             NIDF - Name of input data file.
C
C     The contents of each of the data files is summarized as follows:
C
C     NDBF - contains the probability of hit for a given firer, aim point
C            and target.  An entry of -1. for a particular firer, aim point
C            and target indicates that this probability has not yet been
C            determined.  This file is filled with -1's when the file is
C            initialized.
C
C     NTDF - The target data file contains 10 items about each target in the
C            simulation. These items are listed, as they are stored in the
C            data base, as follows:
C
C             1) Target number which uniquely identifies each target,
C             2) 10 character target description,
C             3) target size, expressed as height and width,
C             4) flag indicating whether target is fixed or random('F'
C                indicates fixed, 'R' indicates random)
C                     a) If fixed, the file contains the fixed position of
C                        the lower left corner of the target relative to the
C                        origin in the target's reference plane and is given
C                        in terms of X and Y coordinates.
C                     b) If random, the file contains the height and width
C                        of a random area in which the target is positioned
C                        and the fixed position of the lower left corner of
C                        the random area relative to the target's reference
C                        reference plane given by an X and Y coordinate.
C             5) flag indicating whether or not the target can fire a weapon
C                ('Y' indicates yes, 'N' indicates no),
C             6) key indicating the weapon type, if the firer has no weapon
C                type(ie - can not fire) a zero is entered,
C             7) number of rounds of ammunition available to the firer,
C             8) the firer's response time(this is the time before the firer
C                fires his first shot),
C                 9) aim points which the firer may fire at listed by priority,
C                    and
C                 10) a list of targets which may be collaterally damaged.
C
C          ADF - The aim point data file contains 4 items which define key aim
C                point information required for the simulation.  These items are
C                listed as follows:
C
C                 1) Aim point number which identifies each aim point uniquely,
C                 2) 10 character aim point description(normally this description
C                    corresponds to the primary target associated with this aim
C                    point),
C                 3) a flag indicating whether the aim point is fixed or random
C                    ('F' indicates fixed, 'R' indicates random) where,
C                          a) if fixed, the fixed position of the aim point is
C                             given relative to the origin in the target reference
C                             plane(not the firer reference plane) by an X and a
C                             Y coordinate,
C                          b) if random, the position and size of a rectangular
C                             random aim area is given by specifing the lower
C                             left corner of the area by an X and a Y coordinate,
C                             and the height and width of the random area, and
C                 4) a list of targets which may be hit by firing at each aim
C                    point.
C
C          OPF - This file contains summarized results obtained from the simula-
C                tion.  Results are classified into three main groups:
C                 1) Probability of hit,
C                 2) probability that a particular target exists with time, and
C                 3) expected number of targets left and conditional probability
C                    that a specific number of targets remain with time.
C
C          IDF - The input data file contains information which identifies the
C                location of aim point, target, and probability of hit data pre-
C                viously entered, gives the duration of the simulation, specifies
C                how often simulation results should be printed, and defines
C                when all target status changes occur.
C
          EQUIVALENCE (PDHF, NAMPDHF(1))
          EQUIVALENCE (TDF,  NAMETDF(1))
          EQUIVALENCE (ADF,  NAMEADF(1))
          EQUIVALENCE (OPF,  NAMEOPF(1))
          EQUIVALENCE (IDF,  NAMEIDF(1))
C
C         Initialize flags used in reading input.
C
          N1 = -1
C
C         FLAG is used to initialize the values used in the probability of hit
C         data base.
C
          FLAG = -1.0
          NZ = 0
          Z = 0.0
          ISTATCF = 0
          JSTATCS = 0
          NSTATCS = 0
```

```
C
C       NTAPE is used to indicate the logical unit number of the primary input
C       device.   NTAPE is initially set to 5, indicating that input is to be
C       obtained interactively from the terminal.  NTAPE is later changed to 1
C       if the input data has been previously stored in a disk file.
C
        NTAPE = 5
C
C       Set the record size(in bytes) of each record contained in the target
C       data base.  The basic record length is 68 plus the length required for
C       aim points and collaterally effected targets.  Each aim point and
C       collateral target number requires 3 characters.
C
        NTRECSZ = 68+3*MAIMPRY+3*MTCOLAT
C
C       Set the record size(in bytes) for records contained in the aim point
C       data file.  3 characters are alloted for each target number which may
C       be hit by firing at a given aim point.
C
        NARECSZ = 41+3*MT-ITGA
        NTMA = NTARGS*MAIMPTS
  100   TYPE *, ' NAME OF INPUT DATA FILE?'
        READ (5, 200, ERR = 100, END = 100) (NAMEIDF(I), I = 1, 5)
  200   FORMAT (5A2)
        OPEN (UNIT = 1, NAME = NIDF, TYPE = 'UNKNOWN', ERR = 14000)
C
C       If the user wishes to modify data in either the aim point or target
C       data base files prior to simulation execution, an 'M' is entered in
C       in response to the next question.  If all input has been entered
C       previously and the user is ready to run, a 'R' is entered.
C
  300   TYPE *, ' MODIFY TARGETS OR RUN? M=MODIFY, R=RUN'
        READ (5, 4800, ERR = 300, END = 300) IDEBUG
        IF (IDEBUG .NE. 'M' .AND. IDEBUG .NE. 'R') GO TO 300
C
C       An attempt is made to read the first record from the input data file
C       If the read is successful, the flag NTAPE is set to 1, specifing that
C       input should come from this file not from the terminal.
C
C       TSTART is the time at which results from the simulation are first
C       printed, the simulation itself in always assumed to begin at TIME=0.
C       TMAX is the maximum time for the simulation to last.
C
        READ (1, *, ERR = 14200, END = 900) TSTART, TMAX
        NTAPE = 1
C
C       DELTAT is the time between result output displays.
C
        READ (1, *, ERR = 14200, END = 14400) DELTAT
C
C       NTITLES is the number of titles used to descibe this simulation.
C
        READ (1, *, ERR = 14200, END = 14400) NTITLES
        DO 500 I = 1, NTITLES
C
```

```
C
C          ITITLES is a character array containing text which describes
C          the current simulation to the user.
C
           READ (1, 400, ERR = 14200, END = 14400) (ITITLE(I, J), J = 1,
     1              MTITLEL)
 400       FORMAT (<MTITLEL>A2)
 500  CONTINUE
C
C     Read other file names from the input file and open these files.
C
      READ (1, 200, ERR = 14200, END = 14400) (NAMEOPF(I), I = 1, 5)
      OPEN (UNIT = 3, NAME = NOPF, TYPE = 'NEW', ERR = 14900, RECORDSIZE =
     1        133)
      READ (1, 200, ERR = 14200, END = 14400) (NAMEDBF(I), I = 1, 5)
      OPEN (UNIT = 2, NAME = NDBF, TYPE = 'UNKNOWN', ERR = 14600, ACCESS =
     1        'DIRECT', RECORDSIZE = 1)
C
C     Read the total number of targets, aim points and target status changes
C     into JTARS, JAIMS and JSTATCS respectively.
C
      READ (1, 600, ERR = 11200, END = 14400) JTARS, JAIMS, JSTATCS,
     1        (NAMETDF(I), I = 1, 5), (NAMEADF(I), I = 1, 5)
 600  FORMAT (3I3, 10A2, 10A2)
      OPEN (UNIT = 4, NAME = NTDF, TYPE = 'UNKNOWN', ERR = 14700, ACCESS =
     1        'DIRECT', RECORDSIZE = NTRECSZ, FORM = 'FORMATTED', RECORDTYPE
     2        = 'FIXED')
      OPEN (UNIT = 7, NAME = NADF, TYPE = 'UNKNOWN', ERR = 14800, ACCESS =
     1        'DIRECT', RECORDSIZE = NARECSZ, FORM = 'FORMATTED', RECORDTYPE
     2        = 'FIXED')
      GO TO 3100
 700  FORMAT (I3, 5A2, 6F7.3, I2, I4, F7.2, <MAIMPRY>I3, <MTCOLAT>I3)
 800  FORMAT (I3, 5A2, 4F7.3, <MTHITGA>I3)
C
C     Receive input interactively, an empty input file was found.  If an end-
C     of-file indicator(CTRL Z) is given in response to the next question,
C     the initialization of aim point, target and probability data bases may
C     be performed.  Examination or modification of specific values in the
C     probability data base can also be accomplished.
C
 900  TYPE *, ' START TIME, END TIME FOR SIMULATION OUTPUT?'
      READ (5, *, ERR = 900, END = 1000) TSTART, TMAX
      IF (TSTART .GE. 0.0) GO TO 2200
      CLOSE (UNIT = 1)
      GO TO 100
1000  TYPE *, ' 1-INITIALIZE PROBABILITY DATA BASE'
      TYPE *, ' 2-INITIALIZE TARGET DATA BASE'
      TYPE *, ' 3-INITIALIZE AIM POINT DATA BASE'
      TYPE *, ' 4-EXAMINE PROB. DATA BASE VALUE'
      TYPE *, ' 5-MODIFY PROB. DATA BASE VALUE'
      READ (5, *, ERR = 1000, END = 900) I
      GO TO (1100, 1300, 1500, 1700, 2000)I
      GO TO 1000
1100  TYPE *, ' NAME OF NEW PROBABILITY DATA BASE FILE?'
      READ (5, 200, ERR = 1100, END = 1100) (NAMEDBF(I), I = 1, 5)
      OPEN (UNIT = 2, NAME = NDBF, TYPE = 'UNKNOWN', ERR = 14600, ACCESS =
      1        'DIRECT', RECORDSIZE = 1)
      NRECMAX = NTMA*(NTARGS-1)+NTARGS*(NAIMPTS-1)+NTARGS
      DO 1200 I = 1, NRECMAX
         WRITE (2'I) FLAG
1200  CONTINUE
      CLOSE (UNIT = 2)
      GO TO 1000
1300  TYPE *, ' NAME OF NEW TARGET DATA BASE FILE?'
      READ (5, 200, ERR = 1300, END = 1300) (NAMETDF(I), I = 1, 5)
      OPEN (UNIT = 4, NAME = NTDF, TYPE = 'UNKNOWN', ERR = 14700, ACCESS =
      1        'DIRECT', RECORDSIZE = NTRECSZ, FORM = 'FORMATTED', RECORDTYPE
      2        = 'FIXED')
      DO 1400 J = 1, NTARGS
         WRITE (4'J, 700) N1, (NAMETDF(I), I = 1, 5), (Z, I = 1, 6), NZ,
      1           NZ, Z, (NZ, I = 1, NAIMPRY), (NZ, I = 1, NTCOLAT)
1400  CONTINUE
      CLOSE (UNIT = 4)
      GO TO 1000
1500  TYPE *, ' NAME OF NEW AIM POINT DATA BASE FILE?'
      READ (5, 200, ERR = 1500, END = 1500) (NAMEADF(I), I = 1, 5)
      OPEN (UNIT = 7, NAME = NADF, TYPE = 'UNKNOWN', ERR = 14800, ACCESS =
      1        'DIRECT', RECORDSIZE = NARECSZ, FORM = 'FORMATTED', RECORDTYPE
      2        = 'FIXED')
      DO 1600 J = 1, NAIMPTS
         WRITE (7'J, 800) N1, (NAMEADF(I), I = 1, 5), (Z, I = 1, 4), (NZ, I
      1           = 1, NIHITGA)
1600  CONTINUE
      CLOSE (UNIT = 7)
      GO TO 1000
1700  TYPE *, ' NAME OF PROBABILITY DATA BASE FILE?'
      READ (5, 200, ERR = 1100, END = 1100) (NAMEDBF(I), I = 1, 5)
      OPEN (UNIT = 2, NAME = NDBF, TYPE = 'UNKNOWN', ERR = 14600, ACCESS =
      1        'DIRECT', RECORDSIZE = 1)
1800  TYPE *, ' ENTER: NFIRER, NAIMPT, NTARGET.'
      READ (5, *, ERR = 1800, END = 1800) I, J, K
      NREC = NTMA*(I-1)+NTARGS*(J-1)+K
      READ (2'NREC) PROB
      WRITE (5, 1900) PROB
1900  FORMAT (' PROB.= ', F10.7)
      CLOSE (UNIT = 2)
      GO TO 1000
2000  TYPE *, ' NAME OF PROBABILITY DATA BASE FILE?'
      READ (5, 200, ERR = 1100, END = 1100) (NAMEDBF(I), I = 1, 5)
      OPEN (UNIT = 2, NAME = NDBF, TYPE = 'UNKNOWN', ERR = 14600, ACCESS =
      1        'DIRECT', RECORDSIZE = 1)
2100  TYPE *, ' ENTER: NFIRER, NAIMPT, NTARGET, PROB.'
      READ (5, *, ERR = 2100, END = 2100) I, J, K, PROB
      NREC = NTMA*(I-1)+NTARGS*(J-1)+K
      WRITE (2'NREC) PROB
      CLOSE (UNIT = 2)
      GO TO 1000
2200  TYPE *, ' TIME INTERVAL AT WHICH RESULTS ARE DISPLAYED?'
      READ (5, *, ERR = 2200, END = 2200) DELTAT
      I = (TMAX-TSTART)/DELTAT
      IF (I .GT. NTMINTS) GO TO 2200
```

```
2300    TYPE *, ' NUMBER OF HARDWARE OPTION TITLES?'
        READ (5, *, ERR = 2300, END = 2300) NTITLES
        IF (NTITLES .GT. MTITLES) GO TO 2300
        DO 2600 I = 1, NTITLES
2400        TYPE *, ' TITLE ', I, '?'
            READ (5, 2500, ERR = 2400, END = 2400) (ITITLE(I, J), J = 1,
        1              MTITLEL)
2500        FORMAT (<MTITLEL>A2)
2600    CONTINUE
2700    TYPE *, ' NAME OF FILE TO CONTAIN RESULTS?'
        READ (5, 200, ERR = 2700, END = 2700) (NAMEOPF(I), I = 1, 5)
        OPEN (UNIT = 3, NAME = NOPF, TYPE = 'UNKNOWN', ERR = 14900, RECORDSIZE
        1        = 133)
2800    TYPE *, ' NAME OF PROBABILITY DATA BASE FILE?'
        READ (5, 200, ERR = 2800, END = 2800) (NAMEDBF(I), I = 1, 5)
        OPEN (UNIT = 2, NAME = NDBF, TYPE = 'UNKNOWN', ERR = 14600, ACCESS =
        1        'DIRECT', RECORDSIZE = 1)
2900    REWIND 1
3000    TYPE *, ' TARGET DATA FILE NAME?'
        READ (5, 200, ERR = 3000, END = 3000) (NAMETDF(I), I = 1, 5)
        OPEN (UNIT = 4, NAME = NTDF, TYPE = 'UNKNOWN', ERR = 14700, ACCESS =
        1        'DIRECT', RECORDSIZE = NTRECSZ, FORM = 'FORMATTED', RECORDTYPE
        2        = 'FIXED')
3100    NTARS = 0
        IF (NTAPE .EQ. 1) GO TO 3200
        TYPE *, ' ENTER TARGET INFORMATION.'
3200    NTARS = NTARS+1
        JFIREF = 0
        JTARGF = 0
3300    IF (NTAPE .EQ. 5) GO TO 3600
        IF (ISTATCF .EQ. 0) GO TO 3400
        IF (JSTATCS .LT. NSTATCS) GO TO 11200
        READ (1, *, ERR = 14200, END = 14400) NUMTAR(NTARS), STATUS(NSTATCS,
        1        1), STATUS(NSTATCS, 2), ISTATUS(NSTATCS, 1)
        GO TO 3500
3400    IF (JTARS .LT. NTARS) GO TO 8400
        READ (1, *, ERR = 14200, END = 14400) NUMTAR(NTARS)
3500    IF (IDEBUG .EQ. 'A') TYPE *, ' TARGET NUMBER: ', NUMTAR(NTARS)
        GO TO 3700
3600    TYPE *, ' TARGET NUMBER?'
        READ (5, *, ERR = 3300, END = 8400) NUMTAR(NTARS)
3700    READ (4'NUMTAR(NTARS), 700) ISKIP, (ITARDES(NTARS, I), I = 1, 5),
        1        (TARCHAR(NTARS, I), I = 1, 6), NWTYPE(NTARS), NROUNDS(NTARS),
        2        EVENTTM(NTARS), (NAIMPRY(NTARS, I), I = 1, MAIMPRY),
        3        (NICOLAT(NTARS, I), I = 1, MICOLAT)
        IF (ISKIP .EQ. -1) GO TO 4100
3800    CONTINUE
        IF (NTAPE .EQ. 1 .AND. IDEBUG .EQ. 'R') GO TO 7500
        TYPE *, ' 1-DESCRIPTION, 2-TARGET HEIGHT, WIDTH'
        TYPE *, ' 3-RANDOM TARGET AREA LOWER COORDINATE'
        TYPE *, ' 4-RANDOM TARGET AREA HEIGHT, WIDTH'
        TYPE *, ' 5-TARGET AREA LOWER COORDINATE'
        TYPE *, ' 6-WEAPON TYPE, 7-AMMUNITION, 8-RESPONSE TIME'
        TYPE *, ' 9-AIM POINTS, 10-COLLATERAL DAMAGE TARGETS'
        READ (5, *, ERR = 3800, END = 7500) I
```

```
         GO TO (3900, 4300, 4600, 5100, 5300, 5900, 6200, 6500, 7000, 7300), I
         GO TO 3800
3900     WRITE (6, 4000) (ITARDES(NTARS, I), I = 1, 5)
4000     FORMAT (' TARGET DESCRIPTION: ', 5A2)
4100     TYPE *, ' TARGET DESCRIPTION?'
         READ (5, 20), ERR = 4100, END = 4200) (ITARDES(NTARS, I), I = 1, 5)
4200     IF (ISKIP .EQ. -1) GO TO 4400
         GO TO 3800
4300     TYPE *, ' TARGET HEIGHT, WIDTH: ', TARCHAR(NTARS, 1),
         1          TARCHAR(NTARS, 2)
4400     TYPE *, ' TARGET HEIGHT, WIDTH?'
         READ (5, *, ERR = 4400, END = 4500) TARCHAR(NTARS, 1), TARCHAR(NTARS,
         1          2)
         JTARGF = 1
4500     IF (ISKIP .EQ. -1) GO TO 4700
         GO TO 3800
4600     TYPE *, ' RANDOM TARGET AREA, LOWER: X COOR., Y COOR.: ',
         1          TARCHAR(NTARS, 3), TARCHAR(NTARS, 4)
         GO TO 4900
4700     TYPE *, ' RANDOM OR FIXED TARGET AREA? F-FIXED, R-RANDOM'
         READ (5, 4800, ERR = 4700, END = 4700) ICHAR
4800     FORMAT (A1)
         IF (ICHAR .NE. 'F' .AND. ICHAR .NE. 'R') GO TO 4700
         IF (ICHAR .EQ. 'F') GO TO 5400
4900     TYPE *, ' RANDOM TARGET AREA, LOWER: X COOR., Y COOR.?'
         READ (5, *, ERR = 4700, END = 5000) TARCHAR(NTARS, 3), TARCHAR(NTARS,
         1          4)
         JTARGF = 1
5000     IF (ISKIP .EQ. -1) GO TO 5200
         GO TO 3800
5100     TYPE *, ' RANDOM TARGET AREA HEIGHT, WIDTH: ', TARCHAR(NTARS, 5),
         1          TARCHAR(NTARS, 6)
5200     TYPE *, ' RANDOM TARGET AREA HEIGHT, WIDTH?'
         READ (5, *, ERR = 5200, END = 5600) TARCHAR(NTARS, 5), TARCHAR(NTARS,
         1          6)
         JTARGF = 1
         GO TO 5600
5300     TYPE *, ' TARGET AREA, LOWER: X COOR., Y COOR. ', TARCHAR(NTARS,
         1          3), TARCHAR(NTARS, 4)
5400     TYPE *, ' TARGET AREA, LOWER: X COOR., Y COOR.?'
         READ (5, *, ERR = 5400, END = 5500) TARCHAR(NTARS, 3), TARCHAR(NTARS,
         1          4)
         JTARGF = 1
5500     TARCHAR(NTARS, 5) = 0.0
         TARCHAR(NTARS, 6) = 0.0
5600     IF (ISKIP .NE. -1) GO TO 3800
5700     TYPE *, ' CAN TARGET FIRE? Y-YES, N-NO'
         READ (5, 4800, ERR = 5700, END = 5700) ICHAR
         IF (ICHAR .NE. 'Y' .AND. ICHAR .NE. 'N') GO TO 5700
         IF (ICHAR .EQ. 'Y') GO TO 5800
         NWTYPE(NTARS) = 0
         EVENTTM(NTARS) = 9999.0
         GO TO 7400
5900     IF (ISKIP .EQ. -1) GO TO 6000
6000     TYPE *, ' WEAPON TYPE: ', NWTYPE(NTARS)
```

```
6000    TYPE *, ' WEAPON TYPE?'
        READ (5, *, ERR = 6000, END = 6100) NWTYPE(NTARS)
        JFIREF = 1
        IF (NWTYPE(NTARS) .LE. 0) EVENTTM(NTARS) = 9999.0
        IF (NWTYPE(NTARS) .GT. NWTYPES) GO TO 6000
6100    IF (ISKIP .EQ. -1) GO TO 6300
        GO TO 3800
6200    TYPE *, ' NUMBER OF ROUNDS AVAILABLE: ', NROUNDS(NTARS)
6300    TYPE *, ' NUMBER OF ROUNDS AVAILABLE?'
        READ (5, *, ERR = 6300, END = 6400) NROUNDS(NTARS)
6400    IF (ISKIP .EQ. -1) GO TO 6600
        GO TO 3800
6500    IF (ISTATCF .EQ. 1) GO TO 6700
        TYPE *, ' RESPONSE TIME: ', EVENTTM(NTARS)
6600    IF (ISTATCF .EQ. 0) GO TO 6800
6700    EVENTTM(NTARS) = 0.0
        GO TO 6900
6800    TYPE *, ' RESPONSE TIME?'
        READ (5, *, ERR = 6800, END = 6900) EVENTTM(NTARS)
6900    IF (ISKIP .EQ. -1) GO TO 7100
        GO TO 3800
7000    TYPE *, ' AIM POINTS(ORDERED BY PRIORITY): ', (NAIMPRY(NTARS, I),
        1        I = 1, NAIMPRY)
7100    TYPE *, ' AIM POINTS(ORDERED BY PRIORITY)?'
        READ (5, *, ERR = 7100, END = 7200) (NAIMPRY(NTARS, I), I = 1,
        1        NAIMPRY)
7200    IF (ISKIP .EQ. -1) GO TO 7400
        GO TO 3800
7300    TYPE *, ' TARGETS DAMAGED BY HITTING THIS TARGET: ',
        1        (NTCOLAT(NTARS, I), I = 1, NTCOLAT)
7400    TYPE *, ' TARGETS DAMAGED BY HITTING THIS TARGET?'
        READ (5, *, ERR = 7400, END = 7200) (NTCOLAT(NTARS, I), I = 1,
        1        NTCOLAT)
        IF (ISKIP .NE. -1) GO TO 3800
7500    WRITE (4'NUMTAR(NTARS), 700) NUMTAR(NTARS), (ITARDES(NTARS, I), I
        1        = 1, 5), (TARCHAR(NTARS, I), I = 1, 6), NWTYPE(NTARS),
        2        NROUNDS(NTARS), EVENTTM(NTARS), (NAIMPRY(NTARS, I), I = 1,
        3        NAIMPRY), (NTCOLAT(NTARS, I), I = 1, NTCOLAT)
        IF (ISTATCF .EQ. 0) GO TO 7800
        IF (NTAPE .EQ. 1) GO TO 7700
7600    TYPE *, ' STATUS CHANGE TIME, INITIAL DELAY, OLD TARGET NUMBER?'
        READ (5, *, ERR = 7600, END = 7600) STATUS(NSTATCS, 1),
        1        STATUS(NSTATCS, 2), ISTATUS(NSTATCS, 1)
7700    ISTATUS(NSTATCS, 2) = NUMTAR(NTARS)
        NSTATCS = NSTATCS+1
7800    IF (ISKIP .EQ. -1 .OR. IDEBUG .EQ. 'M') GO TO 3200
        NF = NUMTAR(NTARS)
        IF (JTARGF .EQ. 0) GO TO 8100
        DO 8000 I = 1, NTARGS
            DO 7900 J = 1, NAIMPTS
                NREC = NTIMA*(I-1)+NTARGS*(J-1)+NF
                WRITE (2'NREC) FLAG
7900        CONTINUE
8000    CONTINUE
8100    IF (JFIREF .EQ. 0 .OR. IDEBUG .EQ. 'M') GO TO 3200
```

```
        DO 8300 I = 1, NAIMPTS
            DO 8200 J = 1, NTARGS
                NREC = NTNA*(F-1)+NTARGS*(I-1)+J
                WRITE (2'NREC) FLAG
8200        CONTINUE
8300    CONTINUE
        GO TO 3200
8400    IF (ISTATCF .EQ. 1) GO TO 11200
        NTAPS = NTAPS-1
        NAIMS = 0
        IF (NTAPE .EQ. 5) GO TO 8500
        READ (1, 4800, ERR = 14200, END = 14400) ISCHAR
        GO TO 8600
8500    TYPE *, ' AIM POINT DATA FILE NAME?'
        READ (5, 200, ERR = 8500, END = 8500) (NAMEADF(I), I = 1, 5)
        OPEN (UNIT = 7, NAME = NADF, TYPE = 'UNKNOWN', ERR = 14800, ACCESS =
        1       'DIRECT', RECORDSIZE = NARECSZ, FORM = 'FORMATTED', RECORDTYPE
        2       = 'FIXED')
        TYPE *, ' ENTER AIM POINT INFORMATION.'
8600    NAIMS = NAIMS+1
        JAIMF = 0
8700    IF (NTAPE .EQ. 5) GO TO 8800
        IF (JAIMS .LT. NAIMS) GO TO 11000
        READ (1, *, ERR = 14200, END = 14400) NUMAIMP(NAIMS)
        IF (IDEBUG .EQ. 'Y') TYPE *, ' AIM POINT NUMBER ', NUMAIMP(NAIMS)
        GO TO 8900
8800    TYPE *, ' AIM POINT NUMBER?'
        READ (5, *, ERR = 8700, END = 11000) NUMAIMP(NAIMS)
8900    READ (7'NUMAIMP(NAIMS), 500) ISKIP, (IAIMDES(NAIMS, I), I = 1,
        1       5), (AIMCHAR(NAIMS, I), I = 1, 4), (NTHITGA(NAIMS, I), I = 1,
        2       NTHITGA)
        IF (ISKIP .EQ. -1) GO TO 9300
9000    CONTINUE
        IF (NTAPE .EQ. 1 .AND. IDEBUG .EQ. 'R') GO TO 8600
        TYPE *, ' 1-DESCRIPTION'
        TYPE *, ' 2-RANDOM AIM POINT AREA LOWER COORDINATE'
        TYPE *, ' 3-RANDOM AIM POINT AREA HEIGHT, WIDTH'
        TYPE *, ' 4-COORDINATES OF FIXED AIM POINT'
        TYPE *, ' 5-TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM POINT'
        READ (5, *, ERR = 9000, END = 10700) I
        GO TO (9100, 9500, 9900, 10100, 10400), I
        GO TO 9000
9100    WRITE (6, 9200) (IAIMDES(NAIMS, I), I = 1, 5)
9200    FORMAT (' AIM POINT DESCRIPTION: ', 5A2)
9300    TYPE *, ' AIM POINT DESCRIPTION?'
        READ (5, 200, ERR = 9300, END = 9400) (IAIMDES(NAIMS, I), I = 1, 5)
9400    IF (ISKIP .EQ. -1) GO TO 9600
        GO TO 9000
9500    TYPE *, ' RANDOM AIM POINT AREA LOWER COOR. ', AIMCHAR(NAIMS, 1),
        1       AIMCHAR(NAIMS, 2)
        GO TO 9700
9600    TYPE *, ' RANDOM OR FIXED AIM POINT? F=FIXED, R=RANDOM'
        READ (5, 1800, ERR = 9600, END = 9600) ICHAR
        IF (ICHAR .NE. 'F' .AND. ICHAR .NE. 'R') GO TO 9600
        IF (ICHAR .EQ. 'F') GO TO 10200
9700    TYPE *, ' RANDOM AIM POINT AREA, LOWER: X COOR., Y COOR?'
```

```
      READ (5, *, ERR = 9700, END = 9800) AIMCHAR(NAIMS, 1), AIMCHAR(NAIMS,
      1         2)
      JAIMF = 1
 9800 IF (ISKIP .EQ. -1) GO TO 10000
      GO TO 9000
 9900 TYPE *, ' RANDOM AIM POINT AREA HEIGHT, WIDTH: ', AIMCHAR(NAIMS,
      1         3), AIMCHAR(NAIMS, 4)
10000 TYPE *, ' RANDOM AIM POINT AREA HEIGHT, WIDTH?'
      READ (5, *, ERR = 10000, END = 10300) AIMCHAR(NAIMS, 3),
      1         AIMCHAR(NAIMS, 4)
      JAIMF = 1
      GO TO 10300
10100 TYPE *, ' COORDINATES OF AIMPOINT: X, Y ', AIMCHAR(NAIMS, 1),
      1         AIMCHAR(NAIMS, 2)
10200 TYPE *, ' COORDINATES OF AIM POINT X, Y?'
      READ (5, *, ERR = 10200, END = 10300) AIMCHAR(NAIMS, 1),
      1         AIMCHAR(NAIMS, 2)
      JAIMF = 1
10300 IF (ISKIP .EQ. -1) GO TO 10500
      GO TO 9000
10400 TYPE *, ' TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM '//
      1         'POINT: ', (NTHITGA(NAIMS, I), I = 1, NTHITGA)
10500 TYPE *, ' TARGETS WHICH MAY BE HIT BY FIRING AT THIS AIM POINT?'
      READ (5, *, ERR = 10500, END = 10600) (NTHITGA(NAIMS, I), I = 1,
      1         NTHITGA)
10600 IF (ISKIP .NE. -1) GO TO 9000
10700 WRITE (7'NUMAIMP(NAIMS), 800) NUMAIMP(NAIMS), (IAIMDES(NAIMS, I),
      1         I = 1, 5), (AIMCHAR(NAIMS, I), I = 1, 4), (NTHITGA(NAIMS, I),
      2         I = 1, NTHITGA)
      IF (ISKIP .EQ. -1 .OR. IDEBUG .EQ. 'N') GO TO 8600
      NAM = NUMAIMP(NAIMS)
      IF (JAIMF .EQ. 0) GO TO 8600
      DO 10900 I = 1, NTARGS
          DO 10800 J = 1, NTARGS
              NREC = NTMA*(I-1)+NTARGS*(NAM-1)+J
              WRITE (2'NREC) FLAG
10800     CONTINUE
10900 CONTINUE
      GO TO 8600
11000 NAIMS = NAIMS-1
      IF (NTAPE .EQ. 1) GO TO 11100
      TYPE *, ' ENTER STATUS CHANGE INFORMATION.'
11100 NTARS = ITARS
      ISTATCF = 1
      NSTATCS = 1
      GO TO 3200
11200 NTARS = ITARS-1
C
C     The following section insures that probabilities of hit are calculated
C     for all combinations of firers, aim points and targets possible.
C     These probabilities of hit are stored both in the data base and in the
C     PTARHIT array.
C
      DO 12100 IDXFIR = 1, NTARS
          IF (NWTYPE(IDXFIR) .EQ. 0) GO TO 12100
```

```
               NF = NUMTAR(IDXFIR)
               DO 12000 IDXAIM = 1, MAIMPRY
                    NAM = NAIMPRY(IDXFIR, IDXAIM)
                    IF (NAM .EQ. 0) GO TO 12100
                    NAMSAVE = NAM
                    DO 11900 IDXTAR = 1, MTHITGA
                         NAM = NAMSAVE
                         NT = NTHITGA(NAM, IDXTAR)
                         IF (NT .EQ. 0) GO TO 12000
                         NREC = MTMA*(NF-1)+MTARGS*(NAM-1)+NT
                         READ (2'NREC) PTH
11300                    FORMAT (F10.7)
                         IF (PTH .NE. -1.0) GO TO 11800
                         DO 11400 J = 1, NAIMS
                              IF (NUMAIMP(J) .EQ. NAM) GO TO 11500
11400                    CONTINUE
                         TYPE *, 'AIM POINT ', NAM, ' COULD NOT BE FOUND.'
                         GO TO 13900
11500                    NAM = J
                         DO 11600 I = 1, NTARS
                              IF (NUMTAR(I) .EQ. NT) GO TO 11700
11600                    CONTINUE
                         TYPE *, ' TARGET: ', NT, ' COULD NOT BE LOCATED.'
                         GO TO 13900
11700                    NT = I
                         CALL GETPTH
                         WRITE (2'NREC) PTH
11800                    PTARHIT(IDXFIR, IDXAIM, IDXTAR) = PTH
11900               CONTINUE
12000          CONTINUE
12100     CONTINUE
          JT = 1
          WRITE (3, 12200)
12200     FORMAT ('1')
          WRITE (3, 12300)
12300     FORMAT (' TARGET DATA:')
C
C         write target and aim point data to output file.
C
          DO 12700 I = 1, NTARS
               IF (I .GT. KTARS) GO TO 12500
               WRITE (3, 12400) NUMTAR(I), (ITARDES(I, J), J = 1, 5), (TARCHAR(I,
          1              J), J = 1, 6), NWTYPE(I), NROUNDS(I), EVENTTM(I),
          2              (NAIMPRY(I, J), J = 1, MAIMPRY), (NTCOLAT(I, J), J = 1,
          3              MTCOLAT)
12400          FORMAT (1X, I3, 1X, 5A2, 1X, 6(F7.3, 1X), I2, 1X, I4, 1X,
          1                   F7.2/,
          2              1X, 3X, 1X, 10X, 1X, <MAIMPRY>(I3, 1X), <MTCOLAT>(1X, I3))
               GO TO 12700
12500          JT = I-KTARS
               WRITE (3, 12600) NUMTAR(I), (ITARDES(I, J), J = 1, 5), (TARCHAR(I,
          1              J), J = 1, 6), NWTYPE(I), NROUNDS(I), EVENTTM(I),
          2              ISTATUS(JT, 1), STATUS(JT, 1), STATUS(JT, 2), (NAIMPRY(I,
          3              J), J = 1, MAIMPRY), (NTCOLAT(I, J), J = 1, MTCOLAT)
12600          FORMAT (1X, I3, 1X, 5A2, 1X, 6(F7.3, 1X), I2, 1X, I4, 1X,
          1                F7.2, 30X, I3, 2(1X, F7.3)/,
          2            1X, 3X, 1X, 10X, 1X, <MAIMPRY>(I3, 1X), <MTCOLAT>(1X, I3))
 12700    CONTINUE
          WRITE (3, 12200)
          WRITE (3, 12800)
 12800    FORMAT (' AIM POINT DATA:')
          DO 13000 I = 1, NAIMS
              WRITE (3, 12900) NUMAIMP(I), (IAIMDES(I, J), J = 1, 5),
          1            (AIMCHAR(I, J), J = 1, 4), (NTHITGA(I, J), J = 1, MTHITGA)
 12900        FORMAT (1X, I3, 1X, 5A2, 4(1X, F7.3), <MTHITGA>(1X, I3))
 13000    CONTINUE
          WRITE (3, 12200)
          JT = JT+1
          NTARS = KTARS
          NSTATCS = NSTATCS-1
          DO 13200 I = 1, MGROUPS
              DO 13100 J = 1, MTARGS
                  ITGROUP(J, I) = 0.0
 13100        CONTINUE
 13200    CONTINUE
          NTGROUP = 1
 13300    IF (NTAPE .EQ. 5) GO TO 13400
C
C         Read optional target groupings for conditional probability calculation
C         after simulation is complete.
C
          READ (1, *, ERR = 14200, END = 13800) NTING
          GO TO 13600
 13400    TYPE *, ' NUMBER OF TARGETS IN GROUP?'
          READ (5, *, ERR = 13400, END = 13800) NTING
 13500    TYPE *, ' TARGETS FOR WHICH CONDITIONAL PROBABILITY SHOULD BE '//
          1        'DISPLAYED?'
          READ (5, *, ERR = 13500, END = 13500) (ITGROUP(I, NTGROUP), I = 1,
          1        NTING)
          GO TO 13700
 13600    READ (1, *, ERR = 14200, END = 14400) (ITGROUP(I, NTGROUP), I =
          1        1, NTING)
 13700    NTGROUP = NTGROUP+1
          IF (NTGROUP .LE. MGROUPS) GO TO 13300
 13800    NTGROUP = NTGROUP-1
          RETURN
 13900    JERROR = 1
          RETURN
 14000    WRITE (6, 14100) (NAMEIDF(I), I = 1, 5)
 14100    FORMAT (' ERROR OPENING FILE: ', 5A2)
          GO TO 13900
 14200    WRITE (6, 14300) (NAMEIDF(I), I = 1, 5)
 14300    FORMAT (' ERROR READING FILE: ', 5A2)
          GO TO 13900
 14400    WRITE (6, 14500) (NAMEIDF(I), I = 1, 5)
 14500    FORMAT (' ERROR - EOF ENCOUNTERED ON: ', 5A2)
          GO TO 13900
 14600    WRITE (6, 14100) (NAMEDBF(I), I = 1, 5)
          GO TO 13900
 14700    WRITE (6, 14100) (NAMEIDF(I), I = 1, 5)
```

```
        GO TO 13900
14800   WRITE (6, 14100) (NAMEADF(I), I = 1, 5)
        GO TO 13900
14900   WRITE (6, 14100) (NAMSUPF(I), I = 1, 5)
        GO TO 13900
        END
```

```
      SUBROUTINE STATCHG
C
C     PURPOSE - Subroutine STATCHG is used to schedule a target status
C               change or group of target status changes. A target status
C               change is a modification to the current qualities that
C               define the target to the model.  Any of the items which are
C               associated with a target in the target data base may be
C               modified.  Examples of modifications include:
C
C               1) change in target size or shape,
C               2) increase or decrease in the amount of ammunition
C                  available,
C               3) selection of new weapon type,
C               4) change in attack or defense force strategy,
C               5) change in aiming time or weapon firing rate, and
C               6) collateral damage effects.
C
C               Status changes will be performed by this routine until the
C               time in which the next status change to occur(STMIN) would
C               exceed the time of the next firing event.
C
      INCLUDE 'W.INC'
      COMMON /L6/ NUMTAR(NTARGS)
      COMMON /L22/ JERROR
      COMMON /L23/ TMAX
      COMMON /L25/ NTARS
      COMMON /L29/ NF
      COMMON /L35/ TMIN
      COMMON /L36/ ISTATUS(NSTATC, 2)
      COMMON /L37/ STATUS(NSTATC, 2)
      COMMON /L38/ NSTATCS
      COMMON /L39/ IDXFIR
      COMMON /L42/ NSTATC
      COMMON /L43/ STMIN
C
C     Search the status change array to determine the index of the last
C     target having minimum status change time.  The index of the next tar-
C     get to undergo a status change is stored in NSTATC and the time at
C     which the status change occurs is stored in STMIN at completion of the
C     following loop.
C
  100 DO 300 I = 1, NSTATCS
         IF (STATUS(I, 1)-STMIN) 200, 300, 300
  200    STMIN = STATUS(I, 1)
         NSTATC = I
  300 CONTINUE
C
C     If the time at which the next firing event is less than the next
C     status change time return to process firing events.
C
      IF (TMIN .LE. STMIN) RETURN
C
C     NF is the number of the target which is to be changed.  This will be
C     considered the old target number. When the status change is made, the
C     old target number in NF is changed indicating that the status change
```

```
C       was completed.
C
        NF = ISTATUS(NSTATC, 1)
C
C       Locate the index of the old target number in the NUMTAR array.  If
C       this target can not be found, an error occured in the initial input
C       data and an error message is printed.
C
        DO 400 IDXFIR = 1, NTARS
            IF (NF .EQ. NUMTAR(IDXFIR)) GO TO 600
  400   CONTINUE
        WRITE (6, 500) NF
  500   FORMAT (' STATUS CHANGE FOR TARGET ', I3, ' IS NOT POSSIBLE.')
        STOP
C
C       Subroutine TAREXEC is called to modify desired parameters associated
C       with the old target number, and assign the new status change target
C       number indicating the target status change has been sucessfully
C       completed.
C
  600   CALL TAREXEC
C
C       The time of the next status change is set greater than the total sim-
C       ulation time forcing a new minimum status change time to be selected
C       before STATCHG returns.
C
        STMIN = TMAX+1.0
C
C       If an error has occured previously in TAREXEC, branch to determine the
C       time and target number for the next status change.
C
        IF (JERROR .EQ. 0) GO TO 100
  700   RETURN
        END
```

```
SUBROUTINE TAREXEC

PURPOSE - Subroutine TAREXEC is called to modify desired parameters
          associated with the old target number, and assign the new
          status change number indicating the target status change
          has been successfully completed.

INCLUDE 'A.INC'
COMMON /L5/ EVENTTM(MTARGS)
COMMON /L6/ NUMTAR(MTARGS)
COMMON /L7/ ITARDES(MTARGS, 5)
COMMON /L8/ TARCHAR(MTARGS, 6)
COMMON /L9/ NATYPE(MTARGS)
COMMON /L10/ NROUNDS(MTARGS)
COMMON /L11/ NAIMPRY(MTARGS, MAIMPRY)
COMMON /L12/ NTCOLAT(MTARGS, MICOLAT)
COMMON /L13/ NUMAIMP(MAIMPTS)
COMMON /L16/ NTHITGA(MAIMPTS, MTHITGA)
COMMON /L19/ PTARHIT(MTARGS, MAIMPRY, MTHITGA)
COMMON /L22/ JERROR
COMMON /L25/ NTARS
COMMON /L26/ NAIMS
COMMON /L29/ NF
COMMON /L30/ NAM
COMMON /L31/ NT
COMMON /L32/ PTH
COMMON /L36/ ISTATUS(MSTATC, 2)
COMMON /L37/ STATUS(MSTATC, 2)
COMMON /L39/ IDXFTR
COMMON /L40/ MTYA
COMMON /L41/ IDXAIM
COMMON /L42/ MSTATC
COMMON /L43/ STATY
COMMON /L45/ IDXTAR
CHARACTER *2 NAMEGPF, NAMEIDF, NAMEDBF, NAMETDF, NAMEADF, IAIMDES,
1         ITARDES

Obtain the old target number pointing to the target information which
was previously used in reference to this target.

NFOLD = ISTATUS(MSTATC, 1)

Obtain the new number which will be used to access the target infor-
mation after the status change has occured.  This number is used by
TAREXEC to locate the data in the target data base which replaces data
obtained by referencing the old target number.

NFNEW = ISTATUS(MSTATC, 2)

Set NF to the new target number.

NF = NFNEW

Read information associated with new target number.
```

```
      READ (4'NFNEW, 100) (TARCHAR(IDXFIR, I), I = 1, 6), NWTYPE(IDXFIR),
     1        NROUNDS(IDXFIR), EVENTTD, (NAIMPRY(IDXFIR, I), I = 1,
     2        NAIMPRY), (MTCOLAT(IDXFIR, I), I = 1, MTCOLAT)
 100  FORMAT (3X, 10X, 6F7.3, I2, I4, F7.2, <NAIMPRY>I3, <MTCOLAT>I3)
C
C     A weapon type of zero indicates that this weapon cannot fire(ie - this
C     is a material type target such as a truck, etc. and not a personnel
C     target).  If this is a material type target, branch.
C
      IF (NWTYPE(IDXFIR) .EQ. 0) GO TO 1100
C
C     If the time before the next player fires is greater than zero, schedule
C     this firer into the queue of players waiting to fire by entering the
C     present time at which the status change is occuring(STMIN) plus the
C     time before the player fires his first shot(STATUS(NSTATC,2).
C
      IF (STATUS(NSTATC, 2) .GT. 0.0) EVENTTM(IDXFIR) = STMIN+STATUS(NSTATC,
     1        2)
C
C     The following section insures that all probabilities associated with
C     this new firer firing at the targets which he can hit are correct.
C
C     IDXAIM is used as an index to specify a particular aim point which the
C     firer can fire at.  IDXAIM is set to 1 initially to specify the first
C     aim point.
C
      IDXAIM = 1
C
C     Obtain the aim point number.
C
 200  NAM = NAIMPRY(IDXFIR, IDXAIM)
C
C     If the aim point number is zero, this indicates that all aim points
C     which the firer can fire at have been examined. In this case the
C     branch is taken and all probabilities have been found which involve
C     this firer firing at other targets.
C
      IF (NAM .EQ. 0) GO TO 1100
C
C     IDXTAR points to the next target which can be hit by firing at this
C     aim point(NAM).
C
      IDXTAR = 1
C
C     NT is the target number of the target which can be hit.
C
 300  NT = NTHITGA(NAM, IDXTAR)
C
C     NT=0 indicates all targets which may be hit by firing at aim point NAM
C     have been investigated and probabilities of hit have been generated.
C
      IF (NT .EQ. 0) GO TO 1000
C
C     NREC is the record number in the probability data base of the record
C     containing the probability that the firer(NF) fires at aim point NAM
```

```
C
C       and hits target NT.
C
        NREC = NTMA*(NF-1)+NTARGS*(NAM-1)+NT
C
C
C       The probability of hit is stored in PTH.
C
        READ (2'NREC) PTH
  400   FORMAT (F10.7)
C
C
C       -1. is used as a special flag which indicates that the probability
C       of hit has not been calculated previously.  If PTH is not equal to
C       -1. it is assumed that it contains the correct probability of hit.
C
        IF (PTH .NE. -1.0) GO TO 900
C
C
C       Locate the index of the target which may be hit in the NUMTAR array.
C       If the target could not be found, an error has occured in the input
C       data and an error message is printed.
C
        DO 500 I = 1, NTARGS
            IF (NUMTAR(I) .EQ. NT) GO TO 600
  500   CONTINUE
        TYPE *, ' TARGET: ', NT, ' COULD NOT BE LOCATED.'
        GO TO 2800
C
C
C       NT is redefined as the index of the target which may be hit.
C
  600   NT = I
C
C
C       Locate the index of the aim point in the NUMAIMP array.  If the index
C       could not be found, an error message is printed indicating an error in
C       input data has been detected.
C
        DO 700 J = 1, NAIMS
            IF (NUMAIMP(J) .EQ. NAM) GO TO 800
  700   CONTINUE
        TYPE *, 'AIM POINT ', NAM, ' COULD NOT BE FOUND.'
        GO TO 2800
C
C
C       NAM is redefined as the index of the aim point in the NUMAIMP array.
C
  800   NAM = J
C
C
C       GETPTH is called to obtain the probability that firer NF fires at aim
C       point NUMAIMP(NAM) and hits target NUMTAR(NT).
C
        CALL GETPTH
C
C
C       Store the probability of hit into the data base.
C
        WRITE (2'NREC) PTH
C
C
C       Store the probability of hit into the PTARHIT array for use by the
C       main program.
C
```

```
  900    PTARHIT(IDXFIR, IDXAIM, IDXTAR) = PTH
C
C        The index to the next target which may be hit by firing at this aim
C        point is incremented.
C
         IDXTAR = IDXTAR+1
C
C        If the index does not exceed the maximum number of targets which may
C        be hit by firing at a given aim point, branch to determine probability
C        that this target is hit.
C
         IF (IDXTAR .LE. MTHITGA) GO TO 300
C
C        Increment index pointing to next aim point which firer may choose to
C        fire at, probabilities of hit have been determined for all targets
C        which may have been hit by firing at the previous aim point.
C
 1000    IDXAIM = IDXAIM+1
C
C        If the number of aim points examined is less than or equal to the max-
C        imum number of aim points allowed, branch to obtain probabilities of
C        hit for all targets associated with the next aim point, otherwise all
C        aim points have been examined and probablilities of hit have been de-
C        termined for all targets which the firer may hit.
C
         IF (IDXAIM .LE. MAIMPRY) GO TO 200
C
C        The following section insures that probabilities of hit have been
C        found for all firers which can hit this target, where 'this target'
C        refers to the target undergoing the status change.
C
C        Save the index of this target.
C
 1100    IDXFSV = IDXFIR
C
C        IDXFIR is used to index the next firer which can hit the status change
C        target.
C
         IDXFIR = 1
C
C        If the weapon type of this firer is 0, this target cannot fire, hence
C        it is ignored because it cannot hit the status change target.
C
 1200    IF (WNTYPE(IDXFIR) .EQ. 0) GO TO 2500
C
C        Obtain the firer number for the firer indexed by IDXFIR.
C
         NF = NUMTAR(IDXFIR)
C
C        Ignore examination of the target which did contain the old information
C        before this status change was performed.
C
         IF (NF .EQ. NFOLD) GO TO 2500
C
C        Search through all of the targets which may be collaterally damaged by
```

```
C      hitting the target pointed to by IDXFIR.  Make sure that if the status
C      change target is one of the targets which may be collaterally damaged,
C      the probability of hit has been calculated.
C
       DO 1300 I = 1, MTCOLAT
C
C          Obtain the index of the next collaterally damaged target.
C
           NTC = NTCOLAT(IDXFIR, I)
C
C          If all collaterally damaged targets have been checked, branch.
C
           IF (NTC .EQ. 0) GO TO 1400
C
C          Ignore examination of the target which did contain the old infor-
C          mation before this status change was performed.
C
           IF (NTC .NE. NEOLD) GO TO 1300
C
C          Store the new status change target number in place of old target
C          number in collaterally damaged target array.
C
           NTCOLAT(IDXFIR, I) = NENEW
 1300  CONTINUE
C
C      This section insures that if this firer should fire at an aim point and
C      and hit the status change target, that the probability that the status
C      change target is hit has been computed previously.
C
C      IDXAIM is initially set to 1, pointing to the first aim point which may
C      be hit by this firer.
C
 1400  IDXAIM = 1
C
C      Obtain the aim point number.
C
 1500  NAM = NAIMPRY(IDXFIR, IDXAIM)
C
C      If the aim point index is zero, all aim points which this firer may
C      select have been examined.
C
       IF (NAM .EQ. 0) GO TO 2500
C
C      The index to the number of targets(IDXTAR) which may be hit by firing
C      at the current aim point(NAM) is initially set to 1.
C
       IDXTAR = 1
C
C      The target number of the next target which may be hit is obtained.
C
 1600  NT = NTHITGA(NAM, IDXTAR)
C
C      The branch is taken after all targets which may be hit by firing at
C      this aim point have been examined.
C
```

```
      IF (NT .EQ. 0) GO TO 2400
C
C     If this target number does not match either the old target number or
C     the new status change target number, then branch.  We are only inter-
C     ested in verifying probabilities of hit associated with these target
C     numbers and changing the old target number to the new target status
C     change number.
C
      IF (NT .NE. NFOLD .AND. NT .NE. NFNEW) GO TO 2300
C
C     Make sure the new target status change number replaces the old target
C     number in the NTHITGA array.
C
      NTHITGA(NAM, IDXTAR) = NFNEW
C
C     Determine the record number of the record containing the probability
C     that this new status change target is hit.
C
      NREC = NPMA*(NF-1)+NTARGS*(NAM-1)+NFNEW
C
C     Read the probability that firer NF fires at aim point NAM and hits
C     the new status change target NFNEW.
C
      READ (2'NREC) PTH
 1700 FORMAT (F10.7)
C
C     Branch if the probability of hit has been previously determined.
C
      IF (PTH .NE. -1.0) GO TO 2200
C
C     Make sure that NT contains the old target number.
C
      IF (NT .EQ. NFNEW) NT = NFOLD
C
C     Find the index of the old target number in the NUMTAR array so that
C     the new status change target number may be entered in place of the
C     old target number in this array.
C
      DO 1800 I = 1, NTARS
          IF (NUMTAR(I) .EQ. NT) GO TO 1900
 1800 CONTINUE
      TYPE *, ' TARGET: ', NT, ' COULD NOT BE LOCATED.'
      GO TO 2900
C
C     Set NT to the index in the array NUMTAR pointing to the old target
C     number.
C
 1900 NT = I
C
C     Obtain the index of the aim point number in the NUMAIMP array.
C
      DO 2000 J = 1, NAIMS
          IF (NUMAIMP(J) .EQ. NAM) GO TO 2100
 2000 CONTINUE
      TYPE *, 'AIM POINT ', NAM, ' COULD NOT BE FOUND.'
      GO TO 2300
C
C     Set NAM to the index of the aim point being fired at in the NUMAIMP
C     array.
C
 2100 NAM = J
C
C     Replace the old target number with the new target status change number
C     in the NUMTAR array.
C
      NUMTAR(NT) = NFNEW
C
C     GETPTH is called to obtain the new probability of hit for the firer NF
C     aiming at the aim point indexed by NAM and hitting the new status
C     change target indexed by NT.
C
      CALL GETPTH
C
C     Store the old target number back into the NUMTAR array so the original
C     target number will be printed in the simulation output.  This statement
C     should be removed when processing more than double level target sub-
C     stitution(ie - when one target assumes more than two positions during
C     the simulation.
C
      NUMTAR(NT) = NFOLD
C
C     Store the newly obtained probability of hit into the probability data
C     base and PTARHIT arrays.
C
      WRITE (2'NREC) PTH
 2200 PTARHIT(IDXFIR, IDXAIM, IDXTAR) = PTH
C
C     Increment IDXTAR to point to the next target which may be hit by firing
C     at this aim point.
C
 2300 IDXTAR = IDXTAR+1
C
C     If IDXTAR is less than or equal to the next target which may be hit by
C     firing at this aim point branch to check if this target number matches
C     either the old target number or the new status change target number.
C     If IDXTAR is greater than the maximum number of targets which may be
C     hit, all targets associated with this aim point have been checked.
C
      IF (IDXTAR .LE. NTHITGA) GO TO 1600
C
C     Increment IDXAIM to point to the next aim point which may be selected
C     by this firer.
C
 2400 IDXAIM = IDXAIM+1
C
C     If the number of aim points examined is less than or equal to the max-
C     imum number of aim points which may be selected, branch to process all
C     targets which may be hit by firing at the next aim point.  If not, all
C     aim points have been examined for this firer.
C
```

```
      IF (IDXAIM .LE. MAIMPRY) GO TO 1500
C
C     Increment the number of firers which have been looked at.
C
 2500 IDXFIR = IDXFIR+1
C
C     If the number of firers is less than or equal to the total number of
C     targets in the simulation, branch and check to see whether the next
C     firer could hit the new status change target.  If not, all possible
C     firers have been examined and probabilities of another firer hitting
C     the new status change target have been correctlyy obtained in the
C     probability data base.
C
      IF (IDXFIR .LE. NTARS) GO TO 1200
C
C     Make sure that all old target numbers have been replaced with the new
C     target status change number in the array containing targets which may
C     be hit by firing at a given aim point, NTHITGA.  This is necessary
C     since the firers examined in the above section may not fire at all
C     aim points in the array and thus the target numbers associated with
C     these aim points have not been checked.
C
C     Loop for all possible aim points.
C
      DO 2700 I = 1, NAIMS
C
C        Loop for all possible targets which may be hit by firing at aim
C        point indexed by I.
C
         DO 2600 J = 1, MTHITGA
C
C           Obtain the target number in NT.
C
            NT = NTHITGA(I, J)
C
C           If all targets which could be hit by firing at this aim point
C           have beeen checked, branch to examine next aim point.
C
            IF (NT .EQ. 0) GO TO 2700
C
C           If the target number is not equal to the old target number,
C           branch and obtain the next target number associated with this
C           aim point.
C
            IF (NT .NE. NFOLD) GO TO 2600
C
C           Store the new status change target number in place of the old
C           target number.
C

            NTHITGA(I, J) = NFNEW
 2600    CONTINUE
 2700 CONTINUE
C
C     Store the new status change target number in place of the old target
```

```
C       number in the NUMTAR array.
C
        NUMTAR(IDXFSV) = NFNEW
C
C       Modify the old target's status change time, indicating that the status
C       change is complete and the old target will not change status again
C       during the simulation.
C
        STATUS(NSTATC, 1) = 9999.0
        RETURN
 2300   JERROR = 1
        RETURN
        END
```

APPENDIX D

GENERATION OF SHOT HIT POINT

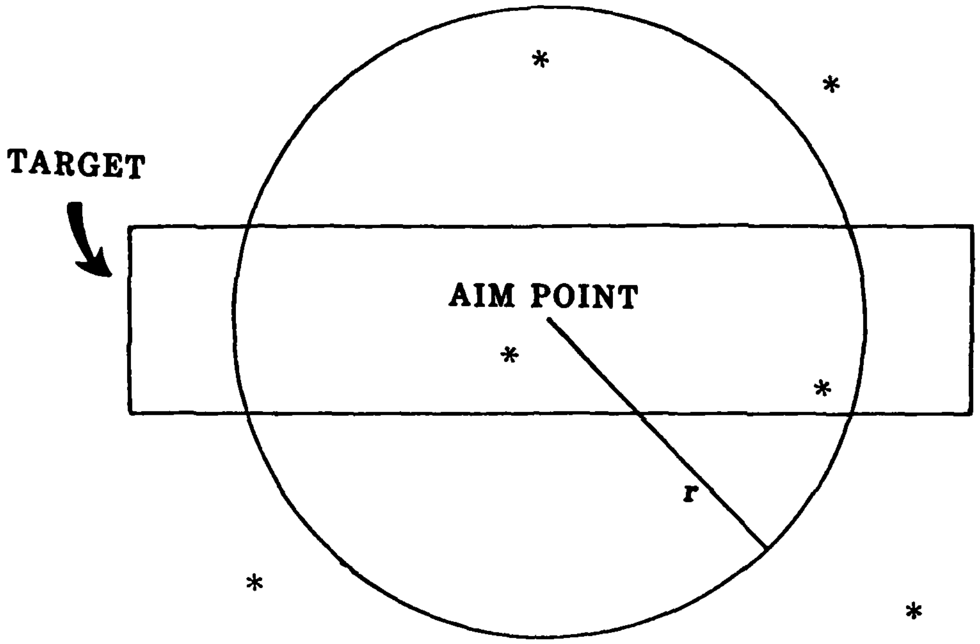
Several factors exist which effect the ability of a firer to hit a particular target at which he may be aiming. Factors effecting a firer's accuracy may be jointly combined to define a probability distribution function which describes the expected dispersion of shots fired at a particular aim point. Accuracy of each weapon type modeled by SAS is defined by a radius (r). The radius defines a circular area centered around the aim point within which one half of all shots fired are expected to land (refer to Figure D.1).

Each shot fired at a particular aim point can be considerd to penetrate the target reference plane at a distance r from the aim point (or origin) at an angle θ. The angle θ is measured from the horizontal as shown in Figure D.2. The assumption is made that the firer is equally likely to miss the aim point in any direction. For example, refering to Figure D.2, the probability that he hits above the aim point is equal to the probability he hits below the aim point. By assuming the probability of hit is equal in any direction, the figure could be rotated at any angle, and the probability of hit above the aim point would equal the probability of hit below the aim point. This assumption implies that θ, the angle in which shots are expected to hit around the aim point, is uniformly distributed over all possible values 0° to 360°.

The distance from the aim point to the hit point (r) is generated by selecting x and y coordinates each from a Gaussian normal distribution having mean μ and standard deviation σ. The density function of the normal random variable x is expressed as:

$$n(x;\mu,\sigma) = \frac{1}{\sqrt{2\pi}\,\sigma}\, e^{-1/2\left\{\frac{x-\mu}{\sigma}\right\}^{2}}$$

Since the probability of hit is equally likely in any direction, the mean value for both x and y is zero, and they will possess the same standard deviation. By assuming that the coordinates x and y are independent, their joint density can be expressed as the product of their individual densities.



$$P(\text{Target is hit}) = \frac{\sum(\text{Number of shots hitting target})}{\text{Total number of shots fired}}$$

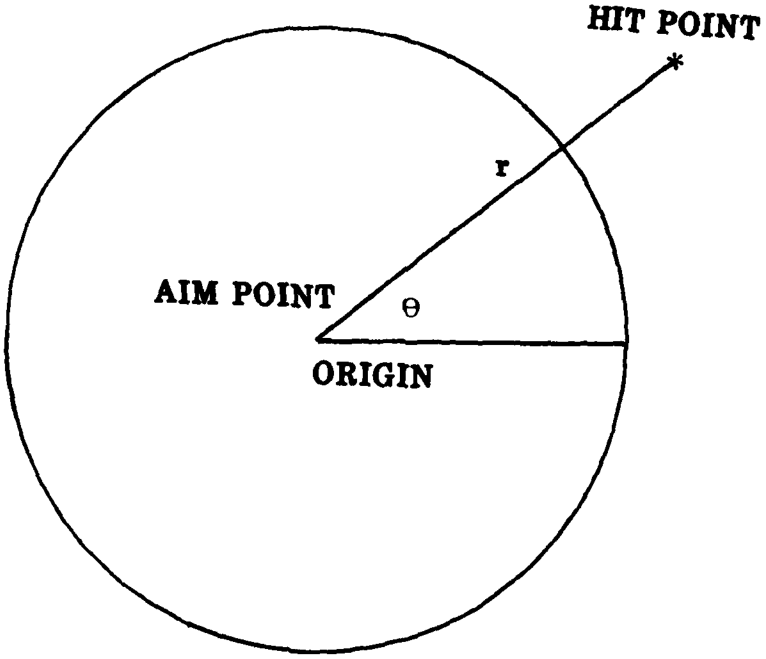
$$= \frac{2}{6} \approx .33, \text{ for this example.}$$

where,

r - Defines the radius of a circle around the aim point within which one-half of all shots fired are expected to land.

* - Denotes a sample hit point selected at random.

Figure D.1 Illustration of Aim Error



where,

r - Distance from origin to hit point.

θ - Angle of hit point from horizontal.

Figure D.2 Hit Point Expressed in Polar Coordinates

Thus,

$$n(x,y;0,\sigma)= \frac{1}{2\pi\sigma^2}\, e^{-\left\{\frac{x^2+ y^2}{2\sigma^2}\right\}}$$

This density function can be expressed in terms of polar coordinates (r,θ) by use of identities:

$$r^2 = x^2 + y^2,\ x = r\cos\theta,\ y = r\sin\theta,\ \text{and } dxdy = rdrd\theta$$

The density function in terms of the distance r from the aim point is given as :

$$f(r)= \frac{r}{\sigma^2}\, e^{(-r^2/ 2\sigma^2)}$$

The density function f(r), known as the Raleigh density, is integrated from 0 to r to obtain the probability that a particular shot will lie within a distance r from the aim point. Performing this integration from 0 to r, where the value of r is the distance from the aim point within which one half of all shots fired are expected to land, allows σ to be expressed as a function of r.

$$P(\text{shot falls within r of aim point}) = \int_0^r f(r)\, dr$$

$$0.5=\int_0^r \frac{r}{\sigma^2}\, e^{-\left\{\frac{r^2}{2\sigma^2}\right\}}\, dr$$

$$= -e^{-\left\{\frac{r^2}{2\sigma^2}\right\}}\Bigg]_0^r$$

$$= - e^{-\left\{\frac{r^2}{2\sigma^2}\right\}} + 1$$

$$= e^{-\left\{\frac{r^2}{2\sigma^2}\right\}}$$

$$\sigma = r\sqrt{\frac{-1}{2\ \ln(.5)}}$$

$$\sigma = 0.8493r$$

Thus, selecting x and y coordinate values from a normal distribution having mean $\mu = 0$ and standard deviation $\sigma = .8493r$ will insure that one half of all shots fired will land within a distance r from the aim point.

To have the computer generate x and y shot coordinates, random numbers U_1 and U_2 are generated by a standard random number generation algorithm. U_1 and U_2 are selected uniformly from the real interval [0., 1.]. These uniform random variables are then used in the following expressions (References 1 and 2) to generate variates which are normally distributed with variance $\sigma = 0.8493r$ and mean $\mu = 0$.

$$x=\cos(2\pi U_2)\sqrt{-1.6986r\log(U_1)}$$

$$y=\sin(2\pi U_2)\sqrt{-1.6986r\log(U_1)}$$

The x and y coordinate values are added to the x and y coordinate values of the aim point to position the shot hit point relative to the origin in the target reference plane. The shot hit point is then checked to see whether or not it penetrated the rectangular target area. If so, a hit is registered. If the weapon has a non-zero lethal kill radius, the distance between the impact point (hit point) of the weapon round within the target reference plane and each corner of the rectangular target area is calculated. If the distance between the hit point and any target area corner is less than the weapon's maximum lethal radius, a hit is registered.

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